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ABSTRACT

Based on a survey of high school programs and courses in the Dallas County Community College District (DCCCD), this articulated program is designed to prepare students for entry-level employment in the air conditioning and refrigeration industry, including residential and commercial air conditioning and commercial refrigeration. The skills and knowledge needed to install, repair, and maintain the equipment in these areas are presented. These courses may be used by DCCCD students to receive a certificate or be applied toward an Associate in Applied Arts and Sciences degree. The manual contains five first-year courses: fundamentals of electricity, advanced electrical circuits, basic principles of refrigeration, vapor compression systems, and pipefitting procedures. Each course is divided into units, and each unit contains the competencies required in the area. Each competency is followed by its criteria, the specific way achievement of that competency is to be measured. Safety tests with answer keys are included in the units as needed. A blank student profile form completes the packet. (KC)

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ED234200

AIR CONDITIONING AND REFRIGERATION PROGRAM ARTICULATION

Dallas County Community College District

An Exemplary Project in
Vocational Education
Funded by the
Texas Education Agency

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1981-1982

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Acknowledgments

The materials in this manual are a result of the cooperation and hard work of several people, most of whom worked on the Articulation Project in addition to their full-time commitments. Appreciation and admiration are extended to each of them.

The Project Director would like to express special gratitude to Frances Whatley, without whose skills and dedication completion of the project would not have been possible; to Faith Helen Farris and Willie Patchen, who worked long and hard on the cover and preparation of materials for printing; and to the many, many people in the Dallas County Community College District who provided assistance, suggestions, guidance, encouragement and a most pleasant atmosphere in which to work.

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Introduction To The Articulation Project

For several years educators have realized that problems exist in the adequate transfer of students from secondary to post-secondary education. This transfer process is especially difficult in the area of occupational education, because too often students enroll in college courses that duplicate the teaching of skills already mastered at the secondary level.

The Dallas County Community College District's Articulation Project, funded by a grant from the Texas Education Agency, is an effort to eliminate duplication of training and facilitate a smooth transition from the high school to the community college.

The following programs have been articulated and are now in use in the DCCCD:

1. Auto Body Technology
2. Auto Mechanics
3. Building Trades-Carpentry
4. Child Development
5. Digital Electronics
6. Drafting and Design Technology
7. Legal Assistant
8. Medical Lab Technician
9. Office Careers
10. Ornamental Horticulture Technology
11. Welding Technology

The programs listed below are now being articulated and will be ready for use at the beginning of the 1982-83 school year:

1. Air Conditioning and Refrigeration
2. Diesel Mechanics
3. Police Science

The major objective of this effort is the preparation of a manual for each of the programs identifying the competencies a student must possess to receive credit for specified courses in the DCCCD. If a student demonstrates mastery at the secondary level, s/he will be granted equivalent credit in the DCCCD.

It is hoped that the articulation process can be expanded to other occupational programs in the future.

Methodology

The Dallas County Community College District (DCCCD) invited area independent school districts offering program(s) to be articulated to participate in the Articulation Project. The names of the participating campuses, districts, and instructors are listed in Appendix.

The college instructors selected the DCCCD's courses that could be articulated, and these served as the blocks. They then listed the major topics in each block, and these became the units. Competencies (an attitude, a skill, or a specific piece of information/knowledge) were developed for each unit. The final step was the development of the criteria, the specific ways to measure mastery of the competencies.

The college instructors then met with the high school instructors to discuss and clarify the articulation materials. Although modifications were made during these discussions, it was understood from the start that the final decisions about requirements were to be made by the college instructors, as it is equivalent DCCCD credit that will be granted.

The reader will note that many of the competencies are preceded by an asterisk. These are the "core competencies," those identified by the college instructors as required for credit for a DCCCD course. The remaining competencies are optional and may be used if the core competencies do not constitute the 80% of competencies needed for credit.

The reader will also note that no methods of teaching are indicated. Only outcomes are defined--approaches to them are left to individual teachers. This was done with the understanding that there is no one and only way to teach and because the diversity of students requries a variety of approaches to teaching and learning.

The Student Profile Sheet is a compilation of all the competencies for each course articulated. It can be used to record a student's achievements, will become a part of her/his official DCCCD record if s/he chooses to apply for credit by articulation, and can also be presented to prospective employers as an indication of the holder's skills and knowledge.

It is clearly understood that this must continue to be a "manual-in-process." Changes will be required if it is to remain current and effective. However, both the framework and methodology for articulation are in place for the future as well as the present.

Articulation Procedures

1. High school personnel notify students of the opportunities available to them through the nontraditional learning policy.

2. a. Students currently enrolled in high school request the Student Profile Sheet form from the high school occupational instructor, master the appropriate competencies, and obtain instructor's signature on the form.

   b. Students who have been out of high school three years or less obtain Student Profile Sheet forms from the college advocate or high school instructor, secure the appropriate high school signatures, and return the form to the college Registrar.

3. Competency form is certified and submitted by the high school to the college Registrar's office by the same procedure as the official transcript is handled.

4. Upon receipt of the student's Application for Admission form by the college Registrar's office, the competency form is placed in the student's permanent record file, and the college advocate is notified.

5. Registrar sends the student a form letter stating:

   a. The equivalent college credits to be awarded and transcripted upon successful completion (C grade or better) of twelve (12) semester credit hours with six (6) credit hours in the student's major occupational area at a DCCCD college. The six (6) credit hours in the student's occupational area will be selected, by the student, from a list of approved courses developed by the faculty of her/his major area.

   b. The advocate's name and telephone number for any additional questions the student may have.

6. The Registrar retains the original copy of the Career Program Articulation form and the form letter in the student's permanent file.

7. The student brings the form letter with him for preregistration counseling at the college.

AIR CONDITIONING AND REFRIGERATION

Cedar Valley College
Eastfield College
North Lake College
of the
Dallas County Community College District

This program is designed to prepare the student for entry level employment in the air conditioning and refrigeration industry, including residential and commercial air conditioning and commercial refrigeration. The skills and knowledge needed to install, repair, and maintain the equipment in these areas are presented.

Students may elect to receive a certificate or may apply the certificate courses required in this program toward an Associate in Applied Arts and Sciences Degree.

This manual contains only five first-year courses.

PLEASE NOTE

THE FOLLOWING MATERIALS ARE NOT INTENDED TO SERVE AS A CURRICULUM GUIDE OR A DESCRIPTION OF A TOTAL PROGRAM.

Although they provide benefits beyond their original intent, these materials were developed for the express purpose of providing a basis for secondary to Dallas County Community College District (DCCCD) articulation.

Only a portion of the total number of courses, usually entry level ones, within a DCCCD program have been articulated. It is important to remember, too, that most of these materials will require periodic updating in order to remain relevant.

Competencies
for the
Air Conditioning and Refrigeration Program

The Air Conditioning and Refrigeration competencies are grouped into the following blocks:

1. Fundamentals of Electricity
2. Advanced Electrical Circuits
3. Basic Principles of Refrigeration
4. Vapor Compression Systems
5. Pipefitting Procedures.

Each block is color-coded. Each block is divided into units, and each unit contains the competencies required in the area.

Each competency is followed by its criteria, the specific way achievement of that competency is to be measured. The criteria do not appear on the Student Profile Sheet.

1. FUNDAMENTALS OF ELECTRICITY

UNITS

Safety

Introduction to Electricity

Meters

Voltage, Current, and Resistance

Ohm's Law

Relationship of Work and Power

Kilowatt Hours

Introduction to Alternating Current and Direct Current

Series Circuits

Parallel Circuits

Series-Parallel Circuits

Common Causes of Circuit Failure

Introduction to Magnetism

Magnetism and Electricity

Induced Voltage

Sine Waves

Resistance and Inductance

Capacitance

Transformers

UNIT: Safety

1.01 * List most common causes of laboratory accidents and ways to prevent them

Causes	Prevention
1. Accidental shocks	1. Keep one hand in pocket. Don't wear conductive jewelry. Don't work while wet or barefoot. Don't bring drinks into lab. Know causes of shock.
2. Equipment misuse	2. Keep work area neat. Know your equipment. Avoid overloads. Use right tool for job. Move machinery carefully. Ground plugs. Connect test leads properly.

1.02 * List general precautions to prevent lab accidents

1. Work with your instructor. Ask questions before proceeding.
2. Never work alone in lab.
3. Be aware of accident possibilities.
4. Get help lifting heavy objects.
5. Take care of equipment.
6. Know where hazards exist and where safety equipment is located.
7. Use extreme caution when working with live circuitry.
8. Shut off all equipment when leaving.
9. Do not get involved in horseplay in lab.
10. Report all accidents to instructor.
11. Be careful. Take your time, think first, plan ahead, and consider the consequences.

1.03 * List steps to take if lab partner receives electrical shock

1. Remove power.
   A. Throw switch or breaker.
   B. Unplug circuit.
2. Send for medical help.
3. If victim is breathing, treat for physical shock.
4. If victim is not breathing, begin artificial respiration, and continue until medical help arrives.

1.04 * Practice good safety habits and correct laboratory procedures

1. According to the above and instructor's directions
2. In all lab work

1.05 Read information sheet on safety

At the end of this block

1.06 * Pass Safety Test

1. At the end of this block
2. With 80% accuracy

UNIT: Introduction to Electricity

1.07 * Define terms and indicate symbols as appropriate

1. Electricity
2. Conductor
3. Insulator
4. Voltage
5. Current
6. Resistance
7. Ohm's Law
8. Work
9. Power
10. Power formula
11. Watt
12. Kilowatt hour
13. Kilowatt hour formula
14. Circuit
15. Polarity
16. Alternating current
17. Direct current
18. Series circuit
19. Parallel circuit
20. Series-parallel circuit
21. Kirchoff's Voltage Law
22. Kirchoff's Current Law
23. Short circuit
24. Open circuit
25. Magnetism
26. Magnetic field
27. Permeability
28. Electromagnetism
29. Induced voltage
30. Sine wave
31. Effective voltage
32. Inductance
33. Capacitance
34. Reactance
35. Power factor
36. Apparent power
37. True power
38. Reactive power

Define terms according to professionally recognized text, dictionary, or other resource.

1.08 * Describe atoms

1. Found in everything
2. Subparticles
   A. Protons
   B. Neutrons
   C. Electrons
3. Made up of nucleus with electrons orbiting around it at very high speed

1.09 * Distinguish between conductors and insulators

1. Conductors allow electricity to flow easily through them.
2. Insulators <u>do not</u> allow electricity to flow easily through them.

1.10 * List 4 good conductors and 4 good insulators

1. Conductors
   A. Silver
   B. Copper
   C. Aluminum
   D. Others according to instructor
2. Insulators
   A. Rubber
   B. Plastic
   C. Glass
   D. Dry wood
   E. Others according to instructor

1.11 * List the 3 terms used to describe force that causes electrons to flow

1. Voltage
2. Electromotive force
3. Difference of potential

1.12 * List 3 common ways to produce voltage

1. Magnetism
2. Chemical action
3. Light
4. Friction
5. Pressure
6. Heat

1.13 List 3 types of conductors used at your facility

1.14 List 3 types of insulators used at your facility

1.15 List 2 methods for producing voltage used at your facility

13 A

UNIT: Meters

1.16 * State meter range switch setting of voltmeter when measuring voltage of unknown value

At highest voltage scale possible

1.17 * State range switch setting when voltmeter is not in use

Off

1.18 * Read AC and DC voltages

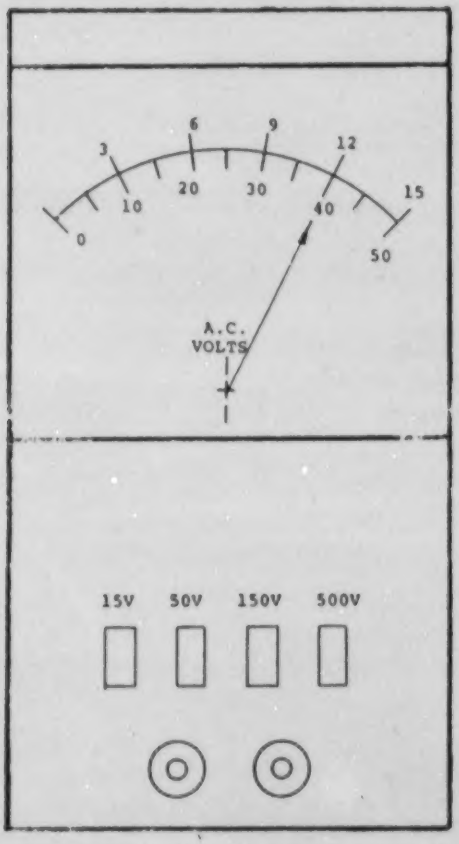
1. As assigned and evaluated by instructor
2. Similar to those below

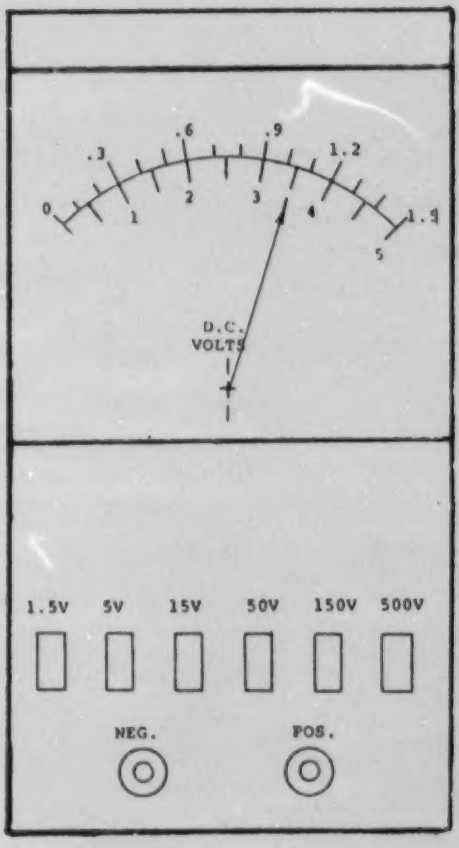
AC volts

Range
15 v_____
50 v_____
150 v_____
500 v_____

DC volts

Range
1.5 v_____
5 v_____
15 v_____
50 v_____
150 v_____
500 v_____





1.19 * State jack in which test probes should be placed when using larger printed values on range switch

1. Black terminal: "Negative" or "common" jack
2. Red terminal: "Positive" jack

1.20 * State why voltmeter should be placed on its back

Meter was calibrated that way and will be more accurate

1.21 * Solve problems involving voltmeter at your work station

1. As assigned and evaluated by instructor
2. Involving:
   A. Calibration with at least 95% accuracy
   B. Maximum voltage and current (AC and DC) from power supply
   C. Voltages that can be varied
   D. Maximum voltages from each position changing function and range switches only
   E. Function and range switch settings for measuring voltage of 24V AC transformer
   F. Voltage drops of prewired circuits
   G. AC and DC voltages with leads in various positions
3. Without damaging meter

1.22 * Select meter(s) capable of measuring resistance in ohms

As assigned and evaluated by instructor

1.23 * State why power must be off when using ohmmeter

When leads of ohmmeter are placed across a device, current flows from power source through device being measured and back to the meter.

1.24 * List 2 reasons ohmmeter should not be left on the ohms scale when not in use

1. Will drain battery
2. Could damage meter (if probes placed across voltage source)

1.25 * State what should be checked whenever ohm scale is changed

Whether or not meter has been "re-zeroed"

1.26 * State proper voltage of circuit when measuring its resistance

No voltage applied

1.27 * State position of function switch when measuring resistance with a multimeter

RX scale

1.28 * List 3 safety rules for working with ohmmeter

1. Do not place leads across potential difference.
2. Do not leave range switch at one of ohms positions when meter is not in use.
3. Place meter in horizontal position for reading.

1.29 * Solve problems involving ohmmeter

1. As assigned and evaluated by instructor
2. Involving:
   A. Correct preparation for use of meter
   B. Unknown resistance values
   C. Series resistors
   D. Identification of open and closed switches and motor terminals
3. With 100% accuracy

1.30 * Select meter(s) capable of measuring current flow in amperes

As assigned and evaluated by instructor

1.31 * State why in-line ammeter should never be placed across a voltage source

1. It should be considered a short-circuit.
2. Current will try to go to infinity.
3. Meter may burn out and/or circuit breaker be tripped.

1.32 * State scale setting of range switch when measuring current

Above current to be read

1.33 * State whether or not voltages used in connection with ammeter can cause electric shock

Yes

1.34 * State shunt switch placement in circuit that will protect in-line ammeter

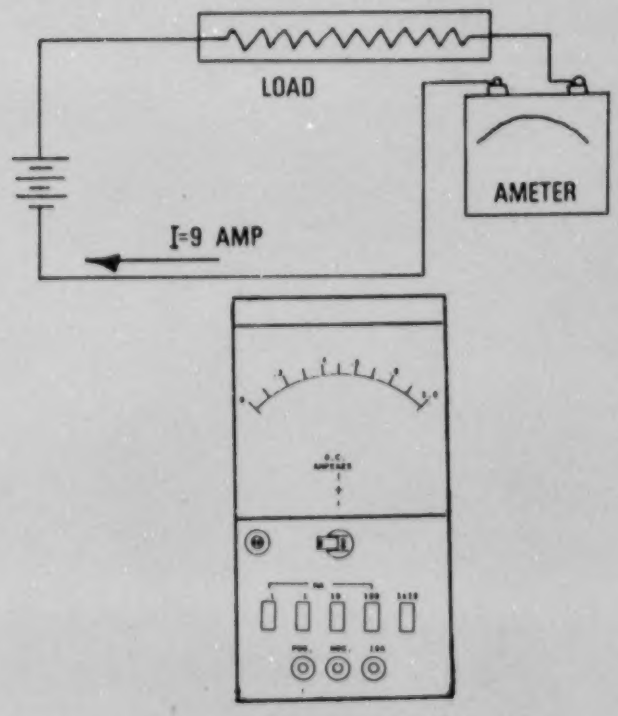
In parallel to meter terminals

1.35 * State scale to start with when placing ammeter in a circuit

Highest

1.36 * Identify needle position, range switch used, and test lead jack

Using situations similar to one below



1.37 * Read current for range switches

Similar to those below

AC Meter

Range

.1A _____

.5A _____

1.0A _____

5A _____

10A _____

DC Meter

Range

.1MA _____

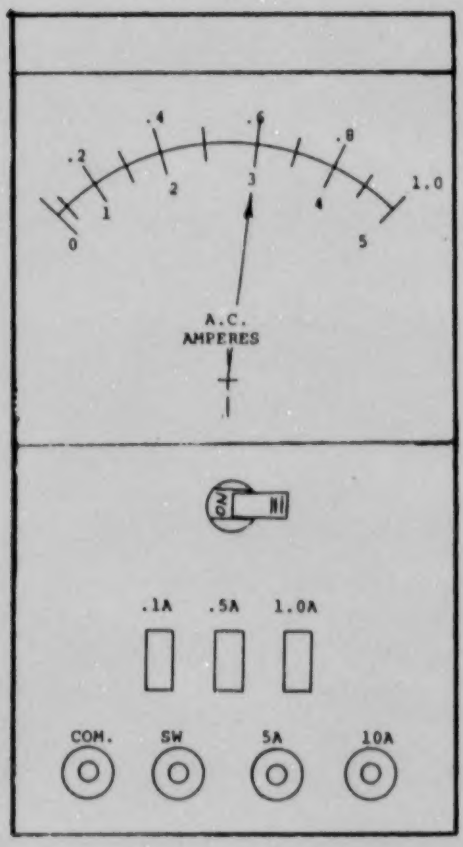
1MA _____

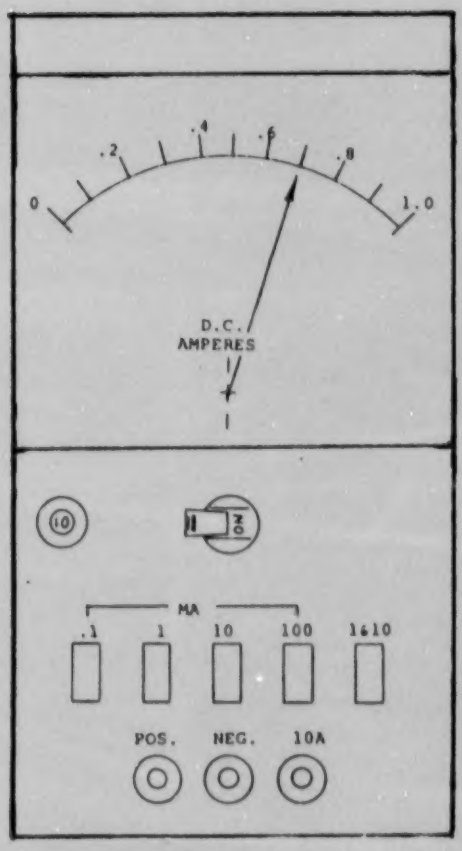
10MA _____

100MA _____

1A _____

10A _____





1.38 * Solve problems using ammeter

1. Setting range switch or scale correctly for each current value to be read
2. Measuring and recording amp readings

UNIT: Voltage, Current, and Resistance

1.39 * List the 3 common measurements of properties of electricity, and give letter symbols for each

1. Voltage: E
2. Current: I
3. Resistance: R

1.40 * Discuss relationship of voltage, current, and resistance

1. Amount of current in circuit is result of amount of voltage and resistance in circuit.
2. Voltage and current are directly related to each other. If resistance remains the same, when voltage goes up, current goes up and vice versa.
3. Resistance opposes current flow. As resistance increases, current decreases and vice versa.
4. Georg Simon Ohm, a German scientist, discovered the relationship.

1.41 * Write Ohm's Law

1. Using words: $\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}$
2. As formula: $I = \frac{E}{R}$

1.42 * State what Ohm's Law is used for

To predict change in current resulting from change in voltage or resistance

UNIT: Ohm's Law

1.43 * Discuss rearrangement of Ohm's Law formula

1. Can be used to determine unknown value if other two values are known
2. Works for all three values
3. Basic formula used to solve for current

1.44 * Rearrange equation to solve for voltage

$$E = I \times R$$

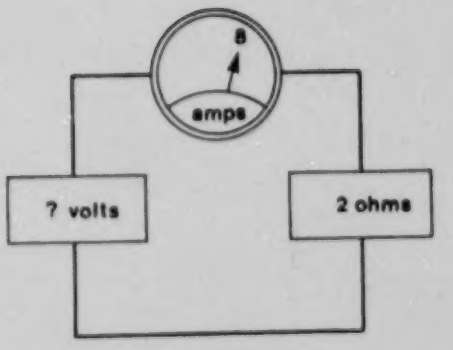
1.45 * Rearrange equation to solve for resistance

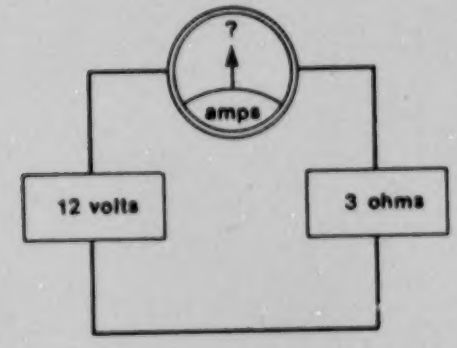
$$R = \frac{E}{I}$$

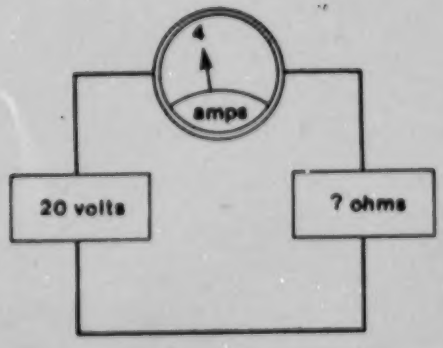
1.46 * Calculate voltage, current, and resistance

1. Given two of three variables
2. For at least six examples provided by instructor

EXAMPLES:







UNIT: Relationship of Work and Power

1.47 * Discuss relationship of work and power

1. Power is rate at which work is done.
2. Rate refers to speed and amount of work being done.
3. The faster the work is done, the more power that is used.
4. The more work is done, the more power that is used.

1.48 * Discuss work and power as they apply to an electrical circuit

1. When voltage causes electrons to flow through a circuit, work is being done.
2. Rate refers to current at a certain applied voltage.
3. Rate (current) can be changed only by changing number or amount of electrons flowing.
4. Rate of electron flow refers to number of electrons passing a single point in the circuit.

1.49 * Describe power formula

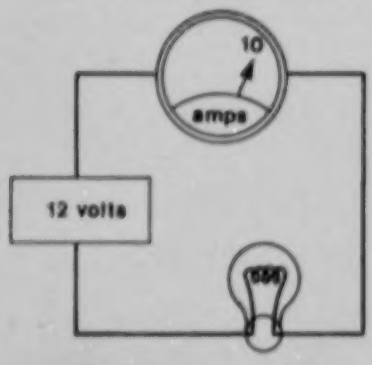
1. Used to determine amount of power in an electrical circuit
2. Result stated in watts
3. Formula: Power = Voltage x Current

$$P = E \times I$$

1.50 * Calculate instantaneous power in simple circuit

1. Given voltage and current
2. In problems provided by instructor

EXAMPLE: How many watts are consumed by the light in this circuit?



UNIT: Kilowatt Hours

1.51 * State formula for watt hours

Watt hours = Watts x Hours of time

1.52 * State number of watts in one kilowatt

1,000

1.53 * State formula for kilowatt hours

Kilowatt hours = Kilowatts x Hours of use

1.54 * Calculate total power consumed over period of time

1. Given instantaneous power
2. In problems provided by instructor

EXAMPLE: Calculate total power given:

1. Circuit uses 5 KW.
2. Circuit operates for 2 1/2 hours.

UNIT: Introduction to Alternating Current and Direct Current

1.55 * List characteristics of a circuit

1. Provides complete path for current to flow through
   A. From source of voltage
   B. Through load
   C. Back to power source
2. Has three basic components
   A. Source of voltage
   B. Conductor
   C. Load
3. May have control devices
   A. Switches
   B. Circuit breakers
   C. Motor starters
   D. Interlocks, etc.

1.56 * Discuss polarity and current flow

1. Involves positive and negative sides of power source
2. Positive side/pole: +
3. Negative side/pole: -
4. Determines direction of current flow through circuit

NOTE: Current flows from negative pole to positive pole in all circuits.

1.57 * List characteristics of direct current (DC)

1. Polarity never changes.
2. Current always flows through circuit in one direction.
3. Power can be stored and is portable.
4. Sources come in variety of types.
   A. Batteries
   B. DC generators
   C. Solar cells
   D. Thermocouples
5. DC sources are commonly used in:
   A. Flashlights
   B. Test instruments
   C. Automobiles.

1.58 * List characteristics of alternating current (AC)

1. Polarity switches back and forth very rapidly at regular intervals.
2. It is the most commonly used type of power.
3. Loads in most industrial facilities are powered by AC as are most home appliances and air conditioners.

1.59 * State why direction of current flow repeatedly reverses itself in an AC circuit

The polarity of the terminals switches back and forth at regular intervals.

1.60 * Draw and label complete circuit

1. Including all components
2. Showing direction of current flow
3. As evaluated by instructor

UNIT: Series Circuits

1.61 * Describe series circuit

1. All loads are connected one after the other.
2. Current flows through each load.
3. There is only one path for current to follow as it flows through circuit.

1.62 * Identify series circuits

From diagrams and actual circuits provided by instructor

1.63 * Draw and label series circuit

As assigned and evaluated by instructor

1.64 * Describe total resistance

The sum of all the resistances (loads) in a series circuit

1.65 * State formula for total resistance in series circuit

$R_T = R_1 + R_2 + \ldots$

1.66 * State what happens to current when total resistance is increased and voltage stays the same

Current decreases.

1.67 * Describe current in series circuit

Level of current is the same throughout the circuit.

1.68 * Describe voltage in series circuit

1. Some is used up as current flows through resistors. This is called voltage drop.
2. Ohm's Law is used to calculate voltage drop.

$$E = I \times R$$

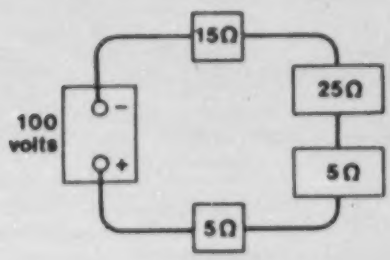
3. Voltage can be referred to as a supply (source voltage) or as a loss (voltage drop).

1.69 * Discuss Kirchoff's Voltage Law

1. Sum of all voltage drops in series circuit is equal to source voltage of the circuit.
2. All voltage is dropped as current flows through circuit.
3. Formula: $E_S = E_1 + E_2 + \ldots$
4. Law is useful when resistance in one part of series circuit is unknown.

1.70 * Calculate unknowns involving resistance in series circuit

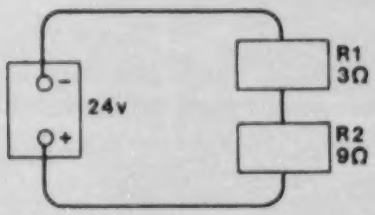
1. Given circuit diagram similar to one below



2. Finding:
   A. Total resistance
   B. Amps of current flowing through circuit
3. Adding 50Ω load to circuit, connected in series
4. Finding:
   A. Total resistance
   B. Whether current increases or decreases
   C. Amount of power in new circuit

1.71 * Calculate unknowns involving current and voltage in series circuit

1. Given circuit diagram similar to one below



2. Finding:
   A. Level of current flowing through circuit
   B. Amount of voltage drop as current flows through each resistor
   C. Amount of voltage drop through R_1 if R_2 is removed from circuit

1.72 * Calculate amounts of current, resistance, and voltage in series circuit constructed by student

1. As assigned and evaluated by instructor
2. Involving at least two loads of known resistance

UNIT: Parallel Circuits

1.73 * Describe parallel circuit

1. Each load is connected in a separate branch in the circuit.
2. There is more than one path for current to follow.
3. Current can flow through one load without flowing through other load(s).

1.74 * Identify parallel circuits

From diagrams and actual circuits provided by instructor

1.75 * Draw and label parallel circuit

As assigned and evaluated by instructor

1.76 * Describe voltage in parallel circuit

Source voltage is applied equally to each branch of circuit.

1.77 * Describe current in parallel circuit

1. Total amount of current is equal to sum of amounts of current flowing through each branch. (Kirchoff's Current Law)
2. Formula: $I_T = I_1 + I_2 + \ldots$

1.78 * List 2 methods for finding total resistance in parallel circuit

1. If voltage and current are known:

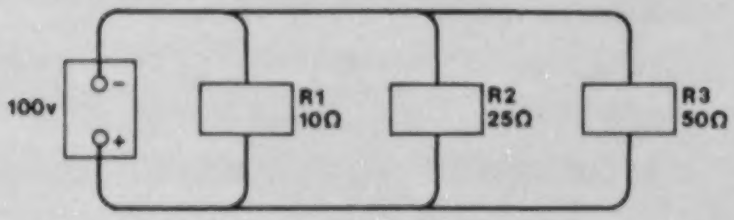
$$R_T = \frac{E}{I_T}$$

2. If resistance value of each resistor is known, and voltage and/or current are unknown:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

1.79 * Calculate unknowns involving current and resistance in parallel circuit

1. Given circuit diagram similar to one below



2. Finding:
   A. Total current
   B. Voltage supplies to branch containing R_2
   C. Total resistance

1.80 * Calculate amounts of current, resistance, and voltage in parallel circuit <u>constructed by student</u>

1. As assigned and evaluated by instructor
2. Involving at least two loads of known resistance

UNIT: Series-Parallel Circuits

1.81 * Describe series-parallel circuit

1. Combination of a series circuit and a parallel circuit
2. Has one or more loads connected in series and two or more connected in parallel

1.82 * Identify series-parallel circuits

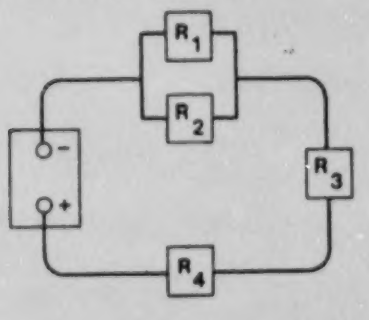
From diagrams and actual circuits provided by instructor

1.83 * Draw and label series-parallel circuit

As assigned and evaluated by instructor

1.84 * Describe current flow through series-parallel circuits

1. Using diagram similar to one below



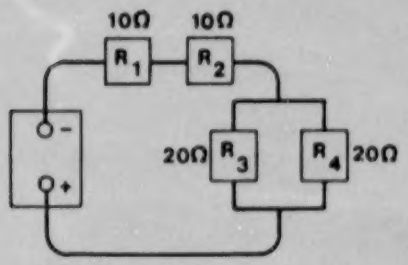
2. Stating whether or not all current must pass through R_3 and reason(s) why or why not

1.85 * Describe way to find total resistance in series-parallel circuit

1. Find resistances within a circuit that are only in series to one another or only parallel to one another.
2. Find total resistance of resistors in series.
3. Find total resistance of resistors in parallel.
4. Add the two totals together.

1.86 * Calculate total resistance in series-parallel circuit

Using diagram similar to one below



1.87 * Calculate total resistance using circuit <u>constructed by student</u>

1. As assigned and evaluated by instructor
2. Involving at least three loads of known resistance in series-parallel

UNIT: Common Causes of Circuit Failure

1.88 * Discuss interruption of current flow

1. Open circuit
   A. Done purposefully with switches
   B. A problem if caused by broken wires or loose connections
2. Short circuit
   A. Occurs when current does not follow its intended path
   B. Occurs if path with less resistance becomes available
   C. Usually causes current to bypass loads and level of current to increase
   D. Can cause fires
   E. Usually protected by fuses, circuit breakers, and overload relays

1.89 * List 3 common causes of short circuits

1. Broken insulation
2. Bare conductors
3. Moisture
4. Incorrect connections

UNIT: Magnetism

1.90 * Discuss properties of magnetism

1. Discovered about 4,000 years ago in stone called magnetite
2. Two poles--north and south
3. Like poles repel and unlike poles attract each other.

1.91 * List 2 characteristics of magnets

1. Natural
   A. Not usually found in useful shapes and sizes
   B. Magnetic properties very weak
2. Artificial
   A. Can be made from iron, steel, and some alloys
   B. Stronger than natural magnets
   C. Magnetized as explained by Domain Theory
   D. Can become demagnitized by being:
      1) Banged or dropped
      2) Heating
      3) Applying reverse magnetic force

1.92 * Discuss types and properties of artificial magnets

1. Types
   A. Permanent: Keep magnetic properties until domains are disturbed
   B. Temporary: Lose most of their magnetic properties when magnetizing force is removed
2. Properties
   A. Residual magnetism: Amount remaining when magnetizing force is removed
   B. Magnetism retained by steel
   C. Most magnetism quickly lost by iron

1.93 * Describe magnetic field or lines of flux

1. Many invisible lines of force surrounding magnet
2. Flow from south to north pole inside magnet
3. Flow from north to south pole outside magnet
4. Form closed loops that never cross each other

1.94 * Describe flux density

1. High near magnet
2. Low further away from magnet
3. Highest in magnet itself

1.95 * Discuss permeability

1. Refers to how easily lines of flux can pass through a material
2. Always take path of highest permeability
3. Highly permeable materials
   A. Sheet steel
   B. Wrought iron
   C. Cast iron
   D. Cast steel
4. Low permeability:
   A. Air
   B. Glass
   C. Wood

1.96 Make a permanent magnet

As assigned and evaluated by instructor

UNIT: Magnetism and Electricity

1.97 * Discuss relationship of magnetism and electricity

1. When current flows through a wire, a magnetic field surrounds the wire.
2. Symbols
   A. Current flowing towards you: ⊙
   B. Current flowing away from you: ⊗
3. When current flow changes direction, magnetic field also changes direction.
4. Magnetic field extends length of wire.

1.98 * Describe reactions of two magnetic fields

1. Magnetic fields around two conductors affect each other.
2. They work together to form stronger field when currents flow in same direction in both conductors.
3. They repel each other when currents flow in opposite directions. If currents are strong enough, the wires will pull apart.

1.99 * Discuss the electromagnet

1. It is created when electric current passes through coil of wire.
2. Creates strong magnetic field around coil.
3. Magnetic field is distorted when current is first applied if piece of permeable metal is placed near center of coil. This is corrected as current continues and metal core moves to center of magnetic field.
4. Coil and piece of metal, which is held inside coil by magnetic field, are referred to as a solenoid.
5. Solenoids are used to operate valves or electrical contacts.

UNIT: Induced Voltage

1.100 * List the 3 elements needed to induce voltage

1. Magnetic field
2. Conductor
3. Relative motion

1.101 * State what is needed for relative motion

Conductor or magnetic field must be moving.

1.102 * Describe what happens when conductor passes through a magnetic field

1. Amount of voltage is changing.
2. Polarity of voltage is changing.
3. Alternating current is created.

1.103 * State what determines amount of voltage induced

Number of lines of flux conductor cuts through in given period of time

1.104 * Discuss effects of conductor movement

1. Cuts straight through lines of flux: Cuts maximum number of lines available, and induces maximum voltage
2. Moves parallel to lines of flux: Cuts no lines, and induces no voltage
3. Moves up and then down: Causes current to flow in first one direction and then opposite direction

UNIT: Sine Waves

1.105 * Describe sine wave

1. Represents change in AC voltage over period of time
2. Plots voltage (vertical axis) against time (horizontal axis)
3. Voltage above horizontal axis positive; voltage below negative
4. Plus and minus values applied arbitrarily
5. Shows one cycle of voltage

1.106 * Discuss cycle of sine wave

1. One complete positive and negative alternation of voltage
2. Each point measured in electrical degrees
3. 360 electrical degrees in one complete cycle
4. First peak at 90°: Maximum positive voltage
5. 180°: Zero
6. Second peak at 270°: Maximum negative voltage

1.107 * State way frequency is expressed

In cycles per second (cps) or, more commonly, hertz (hz)

1.108 * Discuss effective voltage

1. Amount of voltage actually supplied
2. Not as high as peak voltage
3. 70.7% of peak voltage
4. Used in formula for Ohm's Law
5. Also called Root Mean Square (RMS) voltage

1.109 * Draw sine wave

1. Labeling:
   A. Peak voltages
   B. Degrees
   C. One complete cycle
2. As evaluated by instructor

1.110 * Calculate approximate effective value of AC

1. When peak value is known
2. As assigned and evaluated by instructor

UNIT: Resistance and Inductance

1.111 * List the 3 properties which oppose current flow

1. Resistance
2. Inductance
3. Capacitance

1.112 * Describe purely resistive circuit

1. Resistance is only opposition.
2. Current and voltage go up and down together.
3. Sine waves are "in phase."

1.113 * Describe purely inductive circuit

1. Inductance is only opposition.
2. It opposes <u>any</u> change in current flow.
3. Induced voltage opposes applied voltage.
4. Current flows as result of induced voltage.
5. Inductance is measured in henries(h).

1.114 * State whether current leads or lags voltage in an inductive circuit

Lags

1.115 * List 2 practical applications of inductance to AC circuit

1. Suppress current surge
2. Supply high voltage for short period of time

UNIT: Capacitance

1.116 * State way capacitance is measured

1. Farads (fd)
2. Microfarads (μfd)
3. Picofarads (pfd)

1.117 * Describe capacitor

1. Made up of two conductive plates with dielectric between them (Current cannot flow through the dielectric.)
2. Opposes voltage changes by storing applied voltage in form of an electrical charge
3. Transfers electrons from one plate to the other when connected in DC circuit
4. Completely charged when charges of two plates are equal to voltage supply

1.118 * List 2 factors affecting capacitance

1. Surface area of capacitor plates
2. Distance between capacitor plates

1.119 * Describe capacitance in AC circuit

1. Capacitor charged up and current flow maximum first time applied voltage increases in AC circuit
2. Charged and contains same voltage as power source when AC voltage peaks
3. Discharges when applied voltage drops to zero

1.120 * State whether current leads or lags voltage

Leads by 90°

1.121 * State common use for capacitors

To counteract effect of inductance

1.122 State Ohm's Law formulae involving reactance

1. Given:
   X - Reactance
   C - Capacitance
   L - Inductance
2. Purely inductive circuit

   $E = I \times X_L$
3. Purely capacitative circuit

   $E = I \times X_C$

1.123 State formulae for total inductance and total capacitance of circuit

1. Given
   Total inductance (L_T in henries)

   Total capacitance (C_T in farads)
2. Inductors in series:

   $L_T = L_1 + L_2 + \ldots$
3. Inductors in parallel:

   $\frac{1}{L_T} = \frac{1}{L_T} + \frac{1}{L_2} + \ldots$
4. Capacitors in series:

   $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
5. Capacitors in parallel:

   $C_T = C_1 + C_2 + \ldots$
6. Converting to ohms
   A. Dependent upon frequency of applied voltage (in hertz)
   B. Inductance:

      $X_L = 6.28\ fL$
   C. Capacitance

      $X_C = \frac{1}{6.28\ fC}$

1.124 Discuss combined resistance, inductance, and capacitance in an AC circuit

1. Usual situation
2. Requires consideration of phase difference, a complicated mathematical process
3. Gives:
   A. Impedence (Z), or total opposition of circuit, in ohms
   B. Power factor (p.f.) of circuit

1.125 * Discuss power factor

1. Phase difference between current and voltage
2. Usually expressed in percentages (from 0-100%)
3. Can never be more than 90° out of phase
4. Equal amounts of inductance and capacitance = 100% p.f.
5. 80% lagging p.f.: Inductive circuit
6. 80% leading p.f.: Capacitive circuit

1.126 * Describe determination of power in AC circuit

1. Three types of power consumed
   A. Apparent power
      1) Power supplied by source
      2) P_{APP} = E x I = Volt amps (VA)
   B. True (or real) power
      1) Power that actually works
      2) P_T = E x I x p.f. = Watts
   C. Reactive power
      1) Power lost to magnetic fields and capacitive charges
      2) Measured in units of volt amps reactive (VAR)
2. Capacitor bank used by some power companies and large facilities to cut power waste

1.127 * State type of electrical charges that create electrical field when built up

Unlike

UNIT: Transformers

1.128 * State function of transformers and how they operate

1. To change voltage from one value to another
2. By magnetic induction from alternating current

1.129 * List 3 principal parts of transformer and function of each

1. Core: Provides easy path for magnetic lines of flux
2. Primary winding: Receives energy from power source and creates magnetic flux in core
3. Secondary winding: Receives energy from primary winding and delivers it to loads in circuit to which it is connected

1.130 * List the 2 elements influencing voltage output of transformer

1. Input voltage
2. Ratio of number of turns in the two windings

NOTE: Ratio of number of turns in the two windings is in the same proportion as the primary and secondary voltages.

1.131 * Describe step-up and step-down transformers

1. Step-up: Secondary winding has more turns than primary winding
2. Step-down: Primary winding has more turns

1.132 * State purpose of transformers with 1:1 winding ratios

To maintain voltage while electrically isolating primary and secondary circuits

1.133 * State reason alternating current must be applied to primary winding to get voltage in secondary winding

To create alternating magnetic field in core of transformer which provides necessary relative motion for induction in secondary winding

1.134 * Solve problems involving step-up and step-down transformers

Similar to those below:

1. Is a transformer with 300,000 primary winding turns and 15,000 secondary winding turns a step-up or step-down transformer?
2. If there are 1,000 volts on the primary winding of the transformer above, how many volts are on the secondary?
3. What is primary current of transformer with primary voltage of 200V if secondary voltage is 400V and secondary current is 10 amps?

1.135 * Describe effect of voltage changes on current

Increase in voltage causes decrease in current, and decrease in voltage causes increase in current.

1.136 * List and describe the 2 kinds of heat losses in transformers

1. Copper: Caused by heat created by current meeting resistance in the many feet of wire in transformer
2. Core: Occur when reversing magnetic field in core causes metal to heat up

1.137 * Define terms

1. Hysteresis loss
2. Eddy currents
3. Laminations

1.138 * State use of laminations

Help reduce available path for eddy currents

INFORMATION SHEET

A current through the human body in excess of 10 milliamperes can paralyze the victim and make it impossible to let go of a "live" conductor.

If a shock victim is exposed to currents over 100 milliamperes, the shock is often fatal.

Potentials as low as 40 volts can produce a fatal shock if the skin is broken.

Safety is an attitude; safety is knowledge.

STUDY THE FOLLOWING RULES:

1. Investigate before you act.
2. Follow procedures.
3. When in doubt, do not act. Ask your instructor.
4. Do not work when you are tired or taking medicine that makes you drowsy.
5. Do not work in poor light.
6. Do not work in damp areas.
7. Use approved tools, equipment, and protective devices.
8. Do not work if you or your clothing are wet.
9. Remove all rings, bracelets, and similar metal items.
10. Never assume that a circuit is off. Check it with a device or piece of equipment that you are sure is operating properly.
11. Do not tamper with safety devices. Never defeat an interlock switch. Verify that all interlocks operate properly.
12. Keep your tools and equipment in good condition. Use the correct tool for the job.
13. Verify that capacitors have discharged. Some capacitors may store a lethal charge for a long time.
14. Do not remove equipment grounds. Verify that all grounds are intact.
15. Do not use adaptors that defeat ground connections.
16. Use only an approved fire extinguisher.
17. Follow directions when using solvents and other chemicals. They may explode, ignite, or damage electrical circuits.
18. Certain electronic components affect the safe performance of the equipment. Always use the correct replacement parts.

19. Do not attempt to work on complex equipment or circuits before you are ready. There may be many hidden dangers.

20. Some of the best safety information for electrical and electronic equipment is in the literature prepared by the manufacturer. Find it, and use it!

REMEMBER, ALWAYS PRACTICE SAFETY; YOUR LIFE DEPENDS ON IT.

FUNDAMENTALS OF ELECTRICITY

SAFETY TEST

Circle T if the statement is true and F if the statement is false for items 1-17.

T F 1. Do not work when you are tired or taking medicine that makes you drowsy.

T F 2. Do not work in poor light.

T F 3. Do not work in damp areas.

T F 4. Use approved tools, equipment, and protective devices.

T F 5. Work if you or your clothing are wet.

T F 6. Remove all rings, bracelets, and similar metal items.

T F 7. Never assume that a circuit is off. Check it with a device or piece of equipment that you are sure is operating properly.

T F 8. Do not tamper with safety devices. Never defeat an interlock switch. Verify that all interlocks operate properly.

T F 9. Keep your tools and equipment in good condition. Use the correct tool for the job.

T F 10. Verify that capacitors have discharged. Some capacitors may store a lethal charge for a long time.

T F 11. Do not remove equipment grounds. Verify that all grounds are intact.

T F 12. Use adaptors that defeat ground connections.

T F 13. Use only an approved fire extinguisher.

T F 14. Follow directions when using solvents and other chemicals. They may explode, ignite, or damage electrical circuits.

T F 15. Certain electronic components affect the safe performance of the equipment. Always use the correct replacement parts.

T F 16. Attempt to work on complex equipment or circuits before you are ready.

T F 17. Some of the best safety information for electrical and electronic equipment is in the literature prepared by the manufacturer.

Circle the one correct answer for items 18-25.

18. Before working on an electrically operated device, always:

A. Turn off the water.
B. Turn off the power.
C. Stand on a wooden box.
D. Have a helper near.

19. Electrical equipment should be grounded:

A. If it is used in a damp area
B. If the proper tools are available
C. Always
D. Never

20. When attached to a live contact, metal test clips should:

A. Be held off the ground
B. Not touch other metal parts
C. Touch other metal parts
D. Be grounded

21. How many milliamperes can paralyze the victim and make it impossible for him to let go of a "live" conductor?

A. 5 C. 10
B. 100 D. 25

22. How many milliamperes of current flow can be considered fatal?

A. 100 C. 10
B. 25 D. 5

23. Potentials as high as _____ can produce a fatal shock if the skin is open.

A. 10v D. 75v
B. 25v E. 115v
C. 40v

24. Safety is:

A. An attitude
B. Only for beginners
C. Observed only around others
D. All of the above

25. When working with electricity:

A. Investigate before you act.
B. Follow procedures.
C. When in doubt, do not act. Ask your instructor.
D. All of the above

FUNDAMENTALS OF ELECTRICITY

SAFETY TEST
ANSWER KEY

1. T
2. T
3. T
4. T
5. F
6. T
7. T
8. T
9. T
10. T
11. T
12. F
13. T
14. T
15. T
16. F
17. T
18. B
19. C
20. B
21. C
22. A
23. C
24. A
25. D

2. ADVANCED ELECTRICAL CIRCUITS

UNITS

Safety and Basic Electricity Review

Components, Symbols, and Circuitry of Air Conditioning Wiring Diagrams

Alternating Current, Power Distribution, and Voltage Systems

Installation of Heating, Cooling, and Refrigeration Systems

Basic Electric Motors

Components for Electric Motors

Contactors, Relays, and Overloads

Thermostats, Pressure Switches, and Other Electric Control Devices

Troubleshooting Electric Control Devices

Air Conditioning Control Systems

Control Systems: Circuitry and Troubleshooting

Much of the following material is based on Electricity for Refrigeration, Heating, and Cooling by Russell E. Smith, Duxbury Press.

,UNIT: Safety and Basic Electricity Review

Competencies 2.01 through 2.49 come from Fundamentals of Electricity. The criteria remain the same.

2.01 * List most common causes of laboratory accidents and ways to prevent them

2.02 * List general precautions to prevent lab accidents

2.03 * List steps to take if lab partner receives electrical shock

2.04 * Practice good safety habits and correct laboratory procedures

2.05 * Read information sheet on safety

2.06 * Pass Safety Test

2.07 * Read AC and DC voltages

2.08 * Solve problems involving voltmeter at your work station

2.09 * State what should be checked whenever ohm scale is changed

2.10 * State proper voltage of circuit when measuring its resistance

2.11 * Solve problems involving ohmmeter

2.12 * Select meter(s) capable of measuring current flow in amperes

2.13 * State scale to start with when placing ammeter in a circuit

2.14 * Solve problems using ammeter

2.15 * Write Ohm's Law

2.16 * State what Ohm's Law is used for

2.17 * Discuss rearrangement of Ohm's Law

2.18 * Calculate voltage, current, and resistance

2.19 * Discuss relationship of work and power

2.20 * Discuss work and power as they apply to an electrical circuit

2.21 * Describe power formula

2.22 * Calculate instantaneous power in simple circuit

2.23 * State formula for watt hours

2.24 * Calculate unknowns involving resistance in series circuit

2.25 * Calculate unknowns involving current and voltage in series circuit

2.26 * Calculate unknowns involving current and resistance in parallel circuit

2.27 * Calculate amounts of current, resistance, and voltage in parallel circuit constructed by student

2.28 * Calculate total resistance in series-parallel circuit constructed by student

2.29 * Discuss the electromagnet

2.30 * List the 3 elements needed to induce voltage

2.31 * State what is needed for relative motion

2.32 * Describe what happens when conductor passes through a magnetic field

2.33 * Discuss effects of conductor movement

2.34 * Describe sine wave

2.35 * Discuss cycle of sine wave

2.36 * State way frequency is expressed

2.37 * Discuss effective voltage

2.38 * Draw sine wave

2.39 * Calculate approximate effective value of AC

2.40 * List the 3 properties which oppose current flow

2.41 * State whether current leads or lags voltage in an inductive circuit and vice versa

2.42 * State way capacitance is measured

2.43 * Describe capacitor

2.44 * Discuss combined resistance, inductance, and capacitance in an AC circuit

2.45 * Discuss power factor

2.46 * Describe determination of power in AC circuit

2.47 * Describe step-up and step-down transformers

2.48 * State reason alternating current must be applied to primary winding to get voltage in secondary winding

2.49 * Describe effect of voltage changes on current

UNIT: Components, Symbols, and Circuitry of Air Conditioning Wiring Diagrams

2.50 * List the 3 types of electrical diagrams used in heating, cooling, and refrigeration industry and purpose of each

1. Schematic: Show systematic layout of control system
2. Pictorial: Show actual internal wiring of unit
3. Installation: Help installer to wire unit properly

2.51 * Define terms

1. Load
2. "Normally open"
3. "Normally closed"
4. Bimetal element
5. Magnetic overload
6. Schematic diagram
7. Legend (in schematic diagram)
8. Factual diagram

2.52 * State major load of air-conditioning system

Motors

2.53 * Identify and draw symbols for loads

Symbols must be drawn from memory.

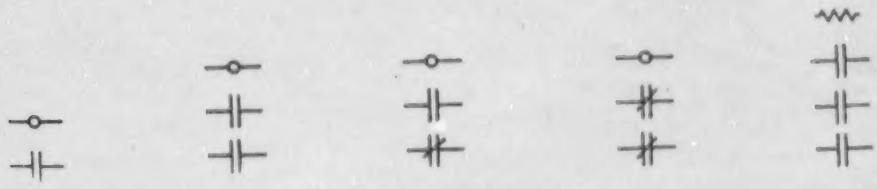
2.54 * State major difference between contactor and relay

1. Size of device
2. Contactor a large relay

2.55 * State difference between magnetic starter and contactor

Magnetic starter has means of overload protection in it; contactor has none.

2.56 * Identify and draw symbols for relays and contactors

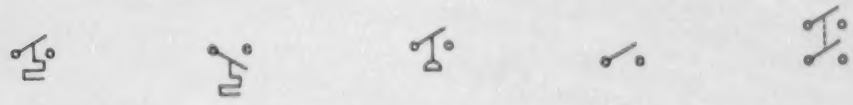


Symbols must be drawn from memory.

2.57 * Explain why heating and cooling thermostats differ

Cooling thermostat is designed to close on a temperature rise and open on a temperature fall. The heating thermostat is just the opposite.

2.58 * Identify and draw symbols for switches

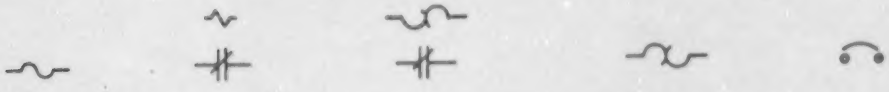


Symbols must be drawn from memory.

2.59 * State purpose of overload

1. To cut off motor immediately when current draw rating is exceeded
2. To prevent damage and possible destruction of component

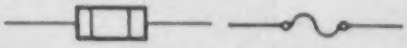
2.60 * Identify and draw symbols for safety devices



Symbols must be drawn from memory.

2.61 * Draw symbol for transformer

2.62 * State purpose of fuse in system, and draw symbols

1. Break the circuit, especially in case of large overload
2. 

UNIT: Alternating Current, Power Distribution, and Voltage Systems

2.63 * Define terms

1. Alternating current
2. Impedance
3. Reactance

2.64 * State most common frequency of alternating current used in U.S.

60 Hz

2.65 * List advantages of alternating current over direct current

1. Equipment is:
   A. Cheaper
   B. More rugged
   C. More trouble free.
2. Current is easier to produce.

2.66 * Describe transmission of alternating current from generating plant to consumer

1. Electricity is generated inside plant.
2. Electricity is transferred outside plant.
3. Power is boosted to large, easily transmitted voltage.
4. Current is transmitted to a substation, and voltage is reduced with step-down transformer.
5. Power is distributed to transformers where voltage is further reduced and then sent to consumer OR sent directly to consumer who uses own transformer to reduce voltage.

2.67 * State most common electrical service to a residence

Single-phase alternating current (230V-1Ø-60 hz)

2.68 * State difference between single-phase and three-phase alternating current

In one cycle, three-phase current will peak six times, and single-phase will peak twice.

2.69 * State voltages of system with Y transformer hookup

1. 208 V-3Ø-60 Hz
2. 460 V-3Ø-60 Hz

2.70 * State voltage of system with delta transformer hookup

230 V-3Ø-60 Hz

2.71 * List an advantage and a disadvantage of delta electric system

1. Advantage: Open delta has only two primary windings.
2. Disadvantage: Caution must be used in hooking 120V devices, because of the "wild leg" on the transformer.

2.72 * Describe detection of Y and delta systems

1. Test across any two hot legs with voltmeter. 230 V indicates delta system.
2. Check between all three hot legs and the ground with voltmeter. If any one of hot legs between ground reads 180-208 V, it is delta system.

2.73 * Identify power in your lab as being a Y or delta system

2.74 * Sketch delta and Y transformer hookup arrangements

As evaluated by instructor

2.75 * List advantages of 208V-3Ø-60Hz system

1. Offers versatility of using three-phase alternating current
2. Offers possibility of supplying many 110-volt circuits

2.76 * Describe type of structures where 208V-3Ø-60Hz systems are used

Structures requiring large number of 110-volt circuits (schools, hospitals, office buildings)

UNIT: Installation of Heating, Cooling, and Refrigeration Systems

2.77 * State who lists standard wire sizes used in U.S. today

American Wire Gauge (AWG)

2.78 List the 4 factors to consider in sizing circuit conductors

1. Voltage drop
2. Insulation type
3. Enclosure
4. Safety

2.79 List major disadvantage of aluminum wiring

Corrodes easily

2.80 Name source service technician should consult for wire-sizing problems

Wire charts from the National Electrical Code

2.81 Define terms

1. Disconnect switch
2. Fusible load center
3. Circuit breaker
4. Full load amperage (FLA)
5. Locked rotor amperage (LRA)

2.82 List the 3 basic types of disconnect switch enclosures

1. General
2. Watertight
3. Explosion proof

2.83 Describe detection of faulty circuit breaker

1. Read voltage between ground and breaker. Breaker is good if voltage is available to load side of breaker under load.
2. Check actual ampere reading of circuit to see if breaker is stuck in closed position or opens prematurely.

2.84 * State most popular conductor in industry today

Copper

2.85 * State purpose of disconnect switch

Disconnecting power supply at the equipment

2.86 * State purpose of main lug in breaker panel

To connect line to breaker panel

2.87 * Describe way to handle situation where no spare opening exists in breaker panel for installing equipment

Install new panel.

2.88 * List formulae for calculating voltage drop

1. $E = IR$
2. $E_d = \frac{22 \times D \times I}{cmil}$

2.89 * Solve problems involving voltage drop

As assigned and evaluated by instructor

EXAMPLE: If a 10-TW wire is 750 ft., what is voltage drop in 230V?

2.90 * Solve problems involving supply voltage

As assigned and evaluated by instructor

EXAMPLE: Determine supply voltage for 100 ft. 4/0 wire if 150 amperes are used on 230V.

2.91 * Solve problems involving wire size

EXAMPLE: Determine size of TW copper wire needed for condensing unit rated at 22 FLA running 50 ft.

2.92 * Identify different types of wire

As assigned and evaluated by instructor

2.93 * Install solderless connectors on various sizes of wire

As assigned and evaluated by instructor

UNIT: Basic Electric Motors

2.94 * Define terms

1. Magnetism
2. Magnetic field
3. Rotor
4. Squirrel cage rotor
5. Shaded-pole motor
6. Split-phase motor
7. Permanent split-capacitor motor
8. Capacitor-start motor
9. Capacitor-start-run motor
10. Torque
11. Electromagnet
12. Stator
13. Microfarad
14. Three-phase motor
15. Run winding
16. Start winding
17. Back electromotive force

2.95 * State what material conducts a magnetic field best

Soft iron

2.96 * State whether or not unlike poles of a magnet repel each other and like poles attract

No

2.97 * Describe part polarity plays in operation of electric motor

Keeps motor moving continuously

2.98 * Discuss part frequency of alternating current plays in operation of electric motor

1. Frequency and number of poles determine motor speed.
2. Approximate motor speed on 60 Hz =

$$\frac{3600}{1/2 \times \text{number of poles}}$$

2.99 * List and identify the 5 types of single-phase motors used in the industry

1. Shaded-pole
2. Split-phase
3. Capacitor-start-run
4. Permanent split-capacitor
5. Capacitor-start

Identify from pictures and actual motors

2.100 * Describe operation of shaded-pole motor

1. Consists of only one winding, part of which is electrically shaded or shunted causing magnetic field in this part of winding to be slightly out-of-phase with rest of winding
2. Starts because of slight out-of-phase winding condition

2.101 * Describe reversing of shaded-pole motor

1. Difficult
2. Requires disassembly
3. Requires reversal of stator

2.102 * Describe why motor with only one winding will not start independently

If rotor should stop where it is equidistant from each pole or aligned with poles, no rotation will be initiated.

2.103 * Describe way split-phase motor produces phase displacement necessary to begin rotation

1. Inductance of start winding is different from run winding.
2. Magnetism in run winding is out-of-phase with start winding.
3. Rotor will initiate rotation no matter where it has stopped.

2.104 * State when split-phase motors are used in relation to torque

When a high starting torque is <u>not</u> required

2.105 * State purpose of centrifugal switch in split-phase motor

To draw starting winding out of circuit when motor reaches 75% of its full speed

2.106 * State purpose of capacitor

To boost the starting torque or running efficiency of single-phase motors

2.107 * List the 2 types of capacitors and the purpose of each

1. Starting (electrolytic): Used to assist single-phase motor in starting
2. Running (oil-filled): Used to assist single-phase motor to run efficiently

2.108 * List the 5 capacitor replacement rules

1. The voltage of any capacitor used for replacement must be equal to or greater than the capacitor being replaced.
2. The strength of the starting capacitor replacement must be at least equal to but not greater than 20% of the capacitor being replaced.
3. The strength of the running capacitor replacement may vary a plus or minus 10% of the capacitor being replaced.
4. If capacitors are installed in parallel, the sum of the capacitors is the total capacitance.
5. The total capacitance of capacitors in series may be found with the following formula:

$$C = \frac{C_1 C_2}{C_1 + C_2}$$

2.109 * Check capacitors

1. Using an ohmmeter
2. Obtaining exact capacitance using the formula below:

$$\text{microfarads} = \frac{2650 \times \text{amperes}}{\text{volts}}$$

3. Using commercial capacitance testers

2.110 * Replace capacitor

As assigned and evaluated by instructor

2.111 * State reason for using capacitor in series with starting winding if winding is in parallel with running winding

1. Start capacitors cause current in start winding to be further out-of-phase with that of run winding.
2. Magnetism in windings will be further out-of-phase creating higher starting torque.

2.112 * State what creates phase displacement in PSC motor

The capacitor in series to the start winding

2.113 * List 4 advantages of using capacitor-start-capacitor-run motor

1. Produces high starting torque
2. Increases running efficiency
3. Combines best features of PSC with capacitor-start feature
4. Produces one of best all-round motors in industry

2.114 * State major difference between split-phase and capacitor-start motors

A capacitor is inserted in series with the centrifugal switch and the starting winding in a capacitor-start motor.

2.115 * State reason starting apparatus is unnecessary when using three-phase motor

1. Three-phase displacement is available because three-phase current gives three hot legs to the device.
2. Current in each winding is already 120° out-of-phase as is magnetism in each winding.

2.116 * List 4 advantages of three-phase motor over single-phase one

1. More rugged
2. More reliable
3. Stronger
4. Does not require starting components

2.117 * State reason all starting apparatus must be mounted externally to hermetic compressor

Nothing can be used inside the shell that may cause a spark or has to move on the crankshaft.

2.118 * List steps in determining common, start, and run terminals of single-phase motor

Use ohmmeter to obtain resistance of each winding with respect to common.

1. Find largest reading between any two terminals. (The remaining terminal is common.)
2. Find largest reading between common and other two terminals. (This is start.)
3. Remaining terminal is run.

2.119 * Determine common, start, and run terminals of single-phase motor

As assigned and evaluated by instructor

2.120 * Determine speed of motor, identify terminals, and check motors for opens, shorts, and shorts to ground

As assigned and evaluated by instructor

2.121 * Draw wiring diagrams of motors

Including all motors previously identified and multi-speed motors

UNIT: Components for Electric Motors

2.122 * State purpose of starting relays

1. To drop starting winding and/or start capacitor out of the circuit
2. Essential to operation of sealed motor compressor

2.123 * Discuss the 3 types of starting relays used in the industry

1. Current
   A. Generally used on small hermetic motors
   B. Operates on current or amperage motor uses to start
   C. Uses electrical characteristics of motor to remove starting circuit electrically once motor has established good running speed
   D. Contacts normally open
   E. Easy to troubleshoot
   F. Coil in series to run winding

2. Hot-wire
   A. Generally used on small hermetic motors
   B. Uses current flow to produce heat across a thermal element to operate starting circuit
   C. Hardest to troubleshoot
   D. In series to run and start winding
   E. Contacts normally closed

3. Potential
   A. Can be adapted to any size unit
   B. Operates on principle of back electromotive force
   C. Contacts normally closed
   D. Easy to troubleshoot
   E. Coil in parallel to start winding

NOTE: All three types:
1. Must be correctly sized and matched with the application.
2. Are designed to remove starting circuit when motor reaches approximately 2/3 or 3/4 full speed.

2.124 * List the 2 types of bearings most used and advantages and disadvantages of each

1. Ball
   A. Advantages
      1) Most efficient
      2) Produce less friction
      3) Mount in any position
      4) Versatile
      5) Able to carry large load
      6) Require less maintenance
      7) Long lasting
   B. Disadvantages
      1) Rapidly destroyed by misuse
      2) More expensive
2. Sleeve
   A. Advantages
      1) Cheaper
      2) More commonly used
   B. Disadvantages
      1) Require more maintenance
      2) Produce more friction
      3) Restricted to lighter loads
      4) Require more care in mounting

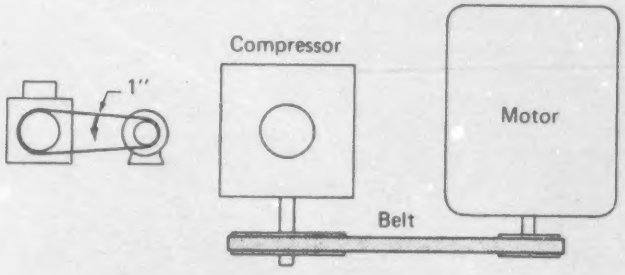
2.125 * Define "direct drive," and state way(s) it is used in the industry

1. Method of transferring rotating motion of motor to device that must be turned; connects motor directly to the device (requiring very close fit) and rotates same revolutions per minute as motor
2. Always used in hermetic compressors; often used in fan motors and pumps

2.126 * State why V-belts are popular in the industry

Not as difficult to align as direct drive

2.127 * Describe correct tension on V-belt



Proper tension and adjustment

2.128 * Set correct tension on V-belt

2.129 * Define terms

1. Arcing
2. Magnetic starter

2.130 * List the 3 types of magnetic starters used in the industry, and describe operation of each

1. Bimetal: Breaks when heated above certain temperature causing starter to open
2. Thermal: Opens contacts when heat is great enough to indicate overload
3. Molten-alloy: Ratchet wheel opens contacts when current flow produces higher-than-normal temperature

2.131 * State whether or not there will be ampere draw through starting circuit after motor reaches full speed with properly working starting relay

1. Split-phase: No
2. Capacitor-start: No
3. Capacitor-start-run: Yes

2.132 * List lubrication methods for both ball and sleeve bearings

1. Ball
   A. Permanent
   B. Packed
2. Sleeve
   A. Oil wick
   B. Yarn-packed
   C. Oil ring

2.133 * State whether or not overlubrication of motor and bearings is as damaging as underlubrication

Yes

2.134 * State where ball bearings cannot be used

In hermetic compressors (because of sparks)

2.135 * Lubricate and check bearings in variety of motors

As assigned and evaluated by instructor

2.136 * Draw wiring diagrams of motors with different types of relays

As assigned and evaluated by instructor

2.137 * Wire up motors and relays

As assigned and evaluated by instructor

UNIT: Contactors, Relays, and Overloads

2.138 * State largest electric load in air conditioning or refrigeration system

Compressor

2.139 * Describe differences between contactors and relays and magnetic starters

1. Contactors can handle large ampacity; relays are usually limited in ampacity.
2. Magnetic starter can house its own overload; contactor cannot.

2.140 * List and describe operation of the 2 types of armatures used in contactors

1. Sliding: Mounts between two slots in frame and moves up and down in the slots
2. Swinging: Mounted on a line and moves up and down in a swinging motion

2.141 * List the 3 major sections of a contactor

1. Armature
2. Coil
3. Contacts

2.142 * State what contactors are made of

Silver and cadmium

2.143 * Describe procedure for checking contactor coil

1. Measure resistance with ohmmeter.
2. Apply voltage, and observe to see if contactor closes.

2.144 * Check contactors

As assigned and evaluated by instructor

2.145 * List 2 major reasons for replacing contacts

1. They must be in good condition to ensure proper voltage reaches load.
2. Excessive voltage drop causes inefficiency.

2.146 * State whether or not voltage reading taken across contacts of same pole will show voltage drop across contacts

Yes

2.147 * State easiest faults to diagnose with contactors

Mechanical linkages

2.148 * List components of relay

1. Coil
2. Contacts
3. Mechanical linkage

2.149 * State whether or not contacts in relay are easy to check by visual inspection

No

2.150 * Define "normally open" and "normally closed" in reference to relays and contactors

1. Open when device is deenergized
2. Closed when device is deenergized

2.151 * State purpose of overload

Protect load from high ampere draw by breaking set of contacts

2.152 * Define "resistive load" and "inductive load"

1. Resistive: Amperage draw constant
2. Inductive: Starts with larger ampere draw and reduces it as load starts normal operation

2.153 * List what fuses are most often used to protect

1. Wires
2. Circuits
3. Noninductive loads

2.154 * State what line break overload breaks

Flow of power to load

2.155 * Describe operation of line break overload

Current draw or temperature of motor causes disc to overheat and expand opening the contact and breaking flow of power.

2.156 * State what pilot duty overload breaks

Auxillary set of contacts connected in control circuit

2.157 * Describe operation of the 2 basic types of pilot duty overloads

1. Current: Similar to line break overload except pilot duty set of contacts is opened rather than the line
2. Magnetic: Magnetic field strong enough to pull core up and open pilot contacts on overload created

2.158 * State advantage of internal compressor overload

Can sense current draw of motor as well as winding temperature more effectively than external overloads

2.159 * Describe procedure for checking internal compressor overload

1. Check motor for open starting and running winding.
2. Check "temperature" of compressor housing.
   A. If cool, motor might be damaged rather than overload.
   B. If warm or hot, overload could be open and working properly.

2.160 * Describe operation of fan relay

Coil is used to close set of contacts to one or more speeds of fan motor.

2.161 * Check fan relay using ohmmeter

As evaluated by instructor

UNIT: Thermostats, Pressure Switches, and Other Electric Control Devices

2.162 * State purpose of thermostat

To control temperatures

2.163 * List the 2 types of thermostats, and describe differences in their operation

1. Heating: Closes on decrease in temperature and opens on increase
2. Cooling: Closes on increase and opens on decrease

2.164 * Describe operation of remote bulb thermostat

Increase or decrease in pressure exerted by diaphragm on mechanical linkage causes contacts to open or close depending on design of thermostat.

2.165 * State why contacts of thermostat should be snap-acting

1. To avoid reactions to minor temperature changes
2. To minimize arcing of contacts

2.166 * List the 2 elements commonly used to provide snap-action

1. Permanent magnet
2. Mercury bulb

2.167 * State where low-voltage thermostat is used

On control systems with 24V supply

2.168 * Describe difference between line voltage and low-voltage thermostats

Size of bimetal element; line voltage larger

2.169 * State purpose of heating anticipator

To anticipate point at which thermostat should open and provide narrow thermostat differential

2.170 * Describe procedure for checking thermostat

1. Check wiring connections.
2. Make sure selector switch and temperature setting are properly selected.
3. Use ohmmeter to be sure switches are closing.

2.171 * State purpose of starting thermostat

To operate equipment at different times according to equipment's needs

2.172 * State why two-stage heating thermostats are used on heat pumps

1. First stage operates compressor.
2. Second operates supplementary heat when first stage cannot handle load.

2.173 * Define terms and letter designations

1. Bimetal
2. System lag
3. Overshoot
4. Cut-in
5. Cut-out
6. Range
7. Differential
8. Pump-down system
9. R
10. Y
11. Y1
12. Y2
13. W1
14. W2
15. G

2.174 * State purposes of low-pressure and high-pressure switches

1. Low: To sense suction pressure
2. High: To sense discharge pressure

2.175 * Describe way low-pressure switch can be used as an operating control on refrigeration system

1. On some systems thermostats are wired in series to a solenoid valve in the liquid line.
2. When valve closes refrigerant flow is blocked, and evaporator pressure decreases until low pressure switch opens and cycles compressor off.
3. This is called a pump-down system.

2.176 * State purpose and describe operation of transformer

1. To provide low-voltage power source for control circuit
2. Transfer electric energy from one circuit to another by induction

2.177 * Describe procedures for checking transformer

1. Use ohmmeter to check continuity of windings.
2. Use voltmeter to check secondary voltage.

2.178 * State way capacity of transformer is rated

1. Electric rating
2. Primary voltage
3. Frequency
4. Secondary voltage
5. Load rating in VA

2.179 * List precautions to take when replacing transformers

1. Select transformer same VA size or larger than one being replaced.
2. Follow manufacturer's directions for new applications.
3. Select transformer with same voltage rating.

2.180 * List the 2 pressures oil safety control operates on in refrigeration systems

1. Oil
2. Suction or crankcase

2.181 * State purpose of time-delay relay

To delay starting of some load for designated time

2.182 * List 3 uses of time clock in heating and cooling system

1. Stop and start defrosting cycle
2. Cut system off and in
3. Others according to instructor

2.183 * Draw wiring diagram of low-voltage thermostat, and identify terminals

As evaluated by instructor

2.184 * Wire low-voltage thermostat into air conditioning circuit

As assigned and evaluated by instructor

2.185 * Wire pressure switches into AC circuit

As assigned and evaluated by instructor

UNIT: Troubleshooting Electric Control Devices

2.186 * State first step in troubleshooting any system or component

Understand its operation and function

2.187 * Describe voltage check to diagnose condition of set of contacts in relay or contactor

1. Take voltage reading from one side of contacts to the other.
2. If voltage loss across contacts exceeds 5% of line voltage, contacts are faulty; and the contactor or relay should be replaced.

2.188 * State difference between open and shorted coil

Open coil will give resistance reading of infinity: shorted coil will read 0Ω.

2.189 * Describe way to check fuse

1. Use ohmmeter.
2. If reading is 0Ω, fuse is good: no continuity indicates bad fuse.

2.190 * Describe way to check circuit breaker

1. Take voltage reading on load side of circuit breaker.
2. If line voltage is read, circuit breaker is probably good.

2.191 * Describe way to proceed if line voltage overload is weak

1. Make amperage check to see what amperage is causing overload to open.
2. If dropout amperage is lower than overload rating, replace device.

2.192 * State difference between line voltage overload and pilot duty overload

1. Line voltage is in series to motor.
2. Pilot duty is in series to relay coil used to control motor.

2.193 * State what must be allowed to happen to hermetic compressor before condemnation

It should be given ample time to cool.

2.194 * List steps in diagnosing bad pressure switch

1. Determine and understand its use in the system.
2. Determine if switch should be opened or closed.
3. Make resistance or voltage check to see if switch is opened or closed.
4. Determine if switch is faulty or system is malfunctioning.

2.195 * Troubleshoot electric control devices, and make needed repairs/replacements

1. As assigned and evaluated by instructor
2. Including:
   A. Contactors
   B. Relays
   C. Overloads
   D. Thermostats
   E. Pressure switches
   F. Transformers
   G. Electric motors
   H. Set of contacts
   I. Fuses
   J. Circuit breaker
3. Using troubleshooting charts as appropriate

UNIT: Air Conditioning Control Systems

2.196 * State purpose of air conditioning control system

To operate system automatically, incorporating all necessary safety equipment by use of thermostat

2.197 * State major difference between controls on small residential condensing unit and large commercial one

Large commercial equipment has more complex control system with more emphasis on safety devices than smaller residential units.

2.198 * Define terms

1. Condensing unit
2. Split air conditioning system
3. Packaged air conditioning unit
4. Gas pack

2.199 * State what internal pressure relief valve replaces in compressor

High-pressure switch

2.200 * Draw diagram of wiring of simple residential air cooled condensing unit

1. Used with a furnace
2. Having:
   A. Contactor
   B. Condenser fan motor
   C. Compressor
3. As evaluated by instructor

2.201 * Describe connection of low and high-pressure switches in electrical system of residential system

High and low pressure switches are normally wired in series to each other.

UNIT: Control Systems: Circuitry and Troubleshooting

2.202 * List 3 components common to all control systems

1. Contactor
2. Condenser fan motor control
3. Safety devices

2.203 * State what controls condenser fan motor on residential systems

Contactor

2.204 * State whether or not safety controls in smaller systems are connected in parallel with contactor coil

No, they are connected in series.

2.205 * State reason capacity control is used on larger systems

Because of variations in the load in the conditioned area

2.206 * Describe function of part winding motor

To allow compressor to start more easily and with less wear and tear

2.207 * State whether or not fan motors in larger systems are generally designed to operate at all times

Yes

2.208 * Describe way constant head pressure is maintained

By operating certain number of condenser fans when outside temperature drops below 75°F

2.209 * Describe function of low-voltage control system in larger systems

To energize main control system

2.210 * Define and describe operation of pump-down control system

1. Control system used on large air conditioning systems and some commercial refrigeration systems
2. Closes solenoid to allow compressor to pump all refrigerant from low side into high side of system

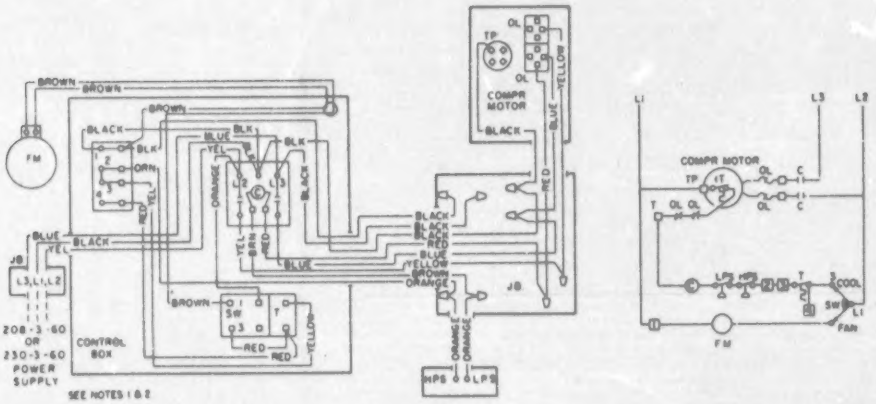
2.211 * Outline general procedure for troubleshooting a control system

1. Check the power supply to the equipment.
2. If no power is available, correct the problem.
3. Make a thorough check of the system to determine which load or loads are not working properly.
4. Locate the loads on the wiring diagram that are not operating properly, and begin checking these circuits first.
5. Each device in that circuit is a possible cause of the problem and should be checked until the faulty device is found. (Do not disregard the load in the circuit.)
6. It may be necessary to move to other circuits to check the coils of some of the devices.
7. Never overlook the internal overload devices.

2.212 * Define "hopscotching"

Troubleshooting procedure for electric circuits involving junping from one component to another

2.213 Describe operation of and solve problems involving "packaged unit"



Legend

C:	Compressor Contactor
COMPR:	Compressor
F:	Fan Contactor
FM:	Fan Motor
HPS:	High-Pressure Switch
IT:	Internal Thermostat
LPS:	Low-Pressure Switch
OL:	Overload Protector
SW:	Selector Switch
T:	Thermostat
⬡ :	Component Connection, Marked
◇ :	Component Connection, Unmarked
□ :	Terminal Board Connection
———	Control Wires
———	Power (factory) Wires
- - - - - - -	Field Wires
— — — —	Alternate CSR Wiring

Notes

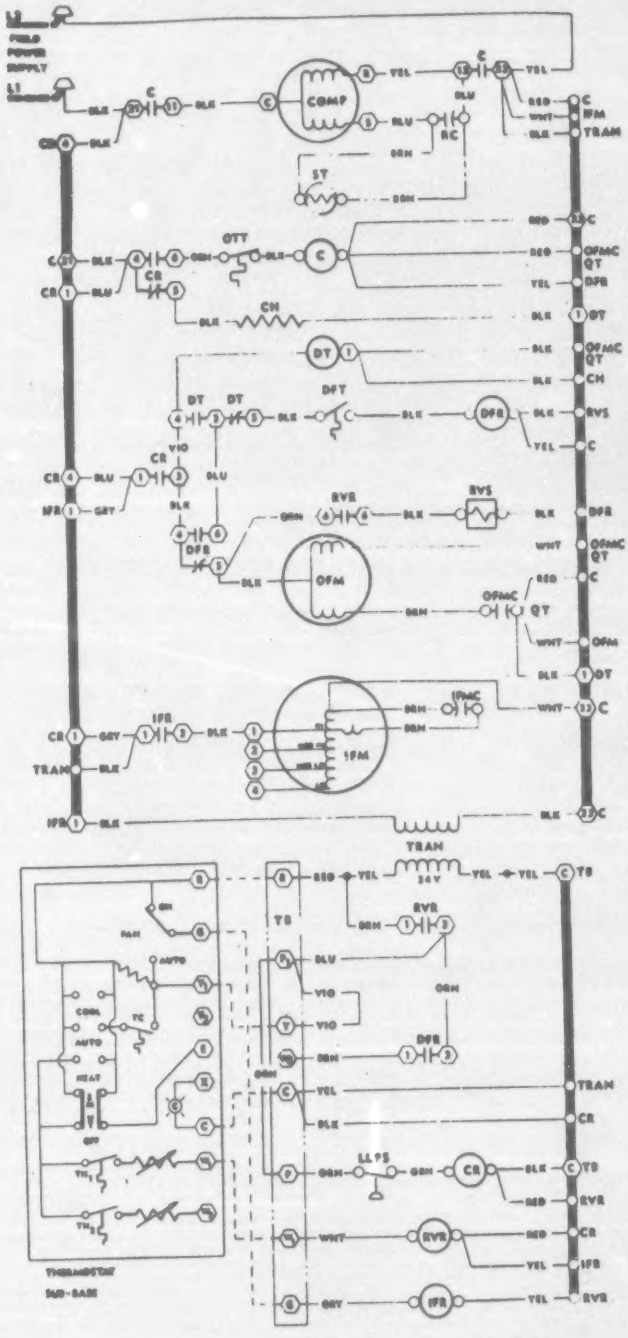
1. Fan motors furnished with inherent thermal protection; compressor motors thermal and overload protection.
2. Control terminal block for connection of Class 1 control circuit.

1. Description of operation is to be evaluated by instructor.
2. Determine problem if contactor is closed but compressor is not working.
3. List safety devices that could prevent contactor from closing if thermostat, selector switch, and two overloads are closed.

2.214 * Describe operation of and solve problems involving heat pump

Legend

C:	Contact
CH:	Crankcase Heater
COMP:	Compressor
CR:	Control Relay
DFR:	Defrost Relay
DFT:	Defrost Thermostat
DT:	Defrost Timer
IFM:	Indoor Fan Motor
IFMC:	Indoor Fan Motor Capacitor
IFR:	Indoor Fan Relay
OFM:	Outdoor Fan Motor
OFMC:	Outdoor Fan Motor Capacitor
QT:	Quad Terminal
RC:	Run Capacitor
RVR:	Reversing Valve Solenoid
TB:	Terminal Block
TRAN:	Transformer
OTT:	Over Temperature Thermostat
LLPS:	Liquid Line Pressure Switch
ST:	Start Thermister



1. Description of operation is to be evaluated by instructor.
2. Name type of thermostat used.
3. List possible problems if control relay is energized but compressor is not operating.
4. State problem if unit will not come out of defrost cycle.

2.215 * Troubleshoot electric control systems, and make needed adjustments/repairs/replacements

1. As assigned and evaluated by instructor
2. Including:
   A. Total system of residential unit
   B. Advanced controls
      1) Compressor motor controls
      2) Water chiller controls
      3) Evaporator fan motor controls
      4) Condenser fan motor controls
      5) Water-cooled condenser interlocks
3. Using troubleshooting charts as appropriate

3. BASIC PRINCIPLES OF REFRIGERATION

UNITS

Heating and Cooling Safety

Fundamentals

Compression System of Refrigeration

Refrigerants

Dehydration

Heat Calculations

Properties of Air

Pressure Enthalpy Diagram

UNIT: Heating and Cooling Safety

3.01 Read information sheet on safety

On the following pages

3.02 * Pass Safety Test

1. At end of this block
2. With 80% accuracy

HEATING AND COOLING SAFETY

INFORMATION SHEET

1. Sharp-pointed tools should be carried pointed toward floor.
2. Oil spots on floor should be cleaned up completely.
3. Damaged tools should not be used at all.
4. Use tools and machinery only if they are in good condition.
5. All tools should be cleaned and neatly stored.
6. For maximum safety, be sure hand tools and machines are in a non-operating position before cleaning, oiling, adjusting, and repairing.
7. Only properly secured clothing should be worn around operating equipment.
8. Extension cords should be placed where they cannot cause tripping.
9. To pull nails with a hammer, pull handle to near vertical, and insert a wedge.
10. A setting hammer is designed for forming and striking sheet metal.
11. The longest screwdriver convenient for a job allows greater control and more power than a shorter one.
12. Before using a hammer, inspect the head to make sure it is firmly secured to the handle.
13. When using a hand drill, turn the crank with constant, even pressure.
14. A properly selected screwdriver fits the slot in the screwhead.
15. Sharp furruled connections should be replaced.
16. Metal surfaces on tools should be lightly oiled.
17. Oily rags should be kept in a covered container.
18. Refrigerant gas can permeate charging hoses and collect under the outer surface.
19. The furnace burner flame will not burn properly without enough combustion air.
20. Products of incomplete combustion are a sign of inefficient use of fuel.
21. A serious explosion can be caused by partially burned raw fuel.
22. Combustion air can be supplied to furnace through separate air duct to outside.
23. A leak in furnace flue pipe is a serious safety hazard.

24. Two important actions to be taken when raw unburned gas is detected near a gas appliance or furnace are to turn off gas and open windows.

25. One of the safest ways to search for gas leaks is soap bubbles.

26. The two actions to be taken when gas odor is detected near a gas furnace that has an electrical spark ignitor are to turn off electrical power to furnace and shut off gas.

27. A separate furnace flue should be installed.

28. If an oil furnace is not operating properly and oil is accumulating in the combustion chamber, shut off all electrical power to furnace and open windows and doors.

29. Voltmeters are used to test voltage.

30. Ohmmeters are used to test continuity.

31. Ammeters are used to test amperage.

32. To test an unknown voltage, set the voltmeter at the highest scale.

33. An ohmmeter can be used to test a dead circuit.

34. For a safe, accurate amperage reading, always attach the ammeter to a single wire.

35. Before working on an electrically operated device, always turn off power.

36. Electrical equipment should always be grounded.

37. When attached to a live contact, metal test clips should not touch other metal parts.

38. If two transformers in the same system are out of phase, they will damage one transformer.

39. Ground a power pack even when it is being repaired on a workbench.

40. Before correcting the malfunction, reset a safety switch only once.

41. A fused disconnect switch should be installed for each power circuit.

42. Special care is required when drilling holes in a control box or unit casing.

43. Voltage imbalance should not exceed 2% in three-phase circuits.

44. A torch flame should never be used on pipes containing refrigerants.

45. High heat from a torch in contact with a refrigerant can cause toxic gases.

46. Toxic gases can cause damage to human respiratory system.

47. An appropriate gas mask should be available when working on systems containing 100 lbs. or more of Group 2 refrigerants.

48. Fusible plugs offer protection to refrigerant cylinder.

49. A cylinder properly filled with refrigerant is safe only at moderate temperatures.

50. To change refrigerant from a liquid to a vapor, use warm water.

51. Using medium pressure range manifold gauges on high pressure systems will damage gauge mechanism.

52. The fusible plug in a refrigerant cylinder softens at 157°F (69°C).

53. The fusible plug in a refrigerant cylinder melts at 165°F (74°C).

54. A refrigerant cylinder should never be completely filled.

55. Refill refrigerant cylinders according to the listed nameplate weight.

56. When changing the refrigerants found in most residential systems, use water at a temperature of 125°F (52°C).

57. ANSI, Group 3 is the most hazardous refrigerant group.

58. To bump a compressor, use a capacitor.

59. The greatest danger in using a headbolt that is too long is that it cannot be tightened adequately.

60. If fan motor rain shield is too tight, motor may overheat.

61. The direction a fan motor should rotate is normally indicated on the fan housing.

62. The compressor shipping plugs should be removed just before the piping is installed.

63. The fan should rotate in the direction of the arrow.

64. Compressors are shipped with the shipping plugs in place.

65. Fan rotation can be changed by switching internal leads.

66. Use a large, open rain shield to prevent motor damage by heat.

67. Slings for rigging should not be used unless the unit has skids.

68. Loosen any shipping bolts, bands, or belts according to manufacturer's instructions before starting the unit.

69. A loose fan belt will slip on its pulley.

70. One-half inch deflection of the fan belt when pressed with the finger is typical.

71. When replacing bearings on a shaft, use light taps with a light hammer.

72. Damaged or flattened fins on cooling and heating coils can decrease efficiency.

73. Before installing electrical accessories, turn off the main power switch.

74. An outside condensing unit should be located to allow space for servicing.

75. When installing refrigerant piping, use vibration isolators.

76. Using an oversized wrench can cause overtightening and damage to the fittings.

77. Using an undersized wrench can cause undertightening and leaks.

78. Using an oversized screwdriver can cause damage to the blade.

79. An undersized screwdriver will not fit the slot.

80. Oiling gaskets reduces friction and causes misalignment.

81. A plastic sleeve protects the joint.

82. A drill which is too long can damage the coils and controls.

83. Heavy work gloves reduce the possibility of cuts.

84. Loose grommets can cause fan and motor damage.

UNIT: Fundamentals

3.03 * Define terms

1. Refrigeration
2. Heat
3. Cold
4. Temperature
5. Fahrenheit, Rankin
6. Centigrade, Kelvin
7. Absolute
8. Heat transfer
9. Conduction
10. Convection
11. Radiation
12. BTU
13. Sensible heat
14. Flash gas
15. Saturation
16. Specific heat
17. Latent heat
18. Latent heat of vaporization
19. Latent heat of fusion
20. Change of state
21. Saturation temperature
22. Super heat
23. Ton of refrigeration
24. Pressure
25. PSIA
26. PSIG
27. Refrigerant
28. Subcooled
29. BTU per hr.

Define according to Carrier GTR or other professionally recognized source.

3.04 * List the 4 temperature scales used in refrigeration

1. Fahrenheit
2. Centigrade
3. Rankin
4. Kelvin

3.05 * List formulae for converting temperatures

1. F° to C°: C° = (F° - 32) x 5/9
2. C° to F°: F° = (9/5 x C°) + 32
3. F° + 460 = Absolute Temperature = R°
4. C° + 273 = Absolute Temperature = K°

3.06 * Convert temperatures among scales

As assigned and evaluated by instructor

3.07 * Describe difference between latent and sensible heat

Sensible heat can be measured with thermometer; latent heat cannot.

3.08 * State BTU needed to change ice to water and water to steam

1. 144 BTU needed to change 1 lb. of 32°F ice into 1 lb. 32°F water
2. 970 BTU needed to change 1 lb. of 212°F water into 1 lb. 212°F steam

3.09 * State sensible heat of water

One

3.10 * List formulae for heat

1. BTU = Weight x Specific Heat x ΔT
2. Total Heat = Sensible Heat + Latent Heat
3. Heat Gain = Heat Loss

3.11 * Solve problems involving heat

As assigned and evaluated by instructor

EXAMPLES:
1. How many BTU must be removed from 212°F steam to convert it to 212°F water?
2. How many BTU must be added to raise temperature of 2 lbs. ice at 0°F to 30°F ice?
3. State time needed to melt 3,000 lbs. ice absorbing 288,000 BTU in 24 hrs.
4. State maximum BTU 1.5 ton air conditioner can remove in 1 hr.

3.12 * Calculate changes in heat of actual substances

1. As assigned and evaluated by instructor
2. Involving
   A. Measuring and recording weights and temperatures
   B. Heat gains and losses

3.13 * State whether or not temperature of melting ice remains constant

Yes

3.14 * List the 3 states of matter

1. Gas
2. Liquid
3. Solid

3.15 * List ways pressure is measured

1. Units of pressure atmospheric (PSIA)
2. Gauge pressure (PSIG)
3. Pressure below atmospheric (PSIG)
4. Vacuum usually given in inches of mercury

3.16 * State what determines conditions at which substance may boil, vaporize, or condense

Pressure

3.17 * List 6 rules governing pressure and temperature

1. Any substance with temperature above absolute 0 contains heat.
2. Higher the temperature of substance the more heat it contains.
3. It is possible to have:
   A. 32°F water and also 32°F ice
   B. 212°F water and also 212°F steam
4. Lowering pressure on substance lowers its boiling point.
5. Water under pressure higher than atmospheric pressure boils at temperature higher than 212°F.
6. Greater the temperature difference, the more rapid the heat flow between product and liquid refrigerant in evaporator.

3.18 * Solve problems involving pressure and temperature

As assigned and evaluated by instructor

EXAMPLES:
1. Using pressure temperature chart, determine boiling point of R-22 at 70 PSI.
2. State result of lowering pressure on container of R-12 from 60 PSI to 10 PSI.

3.19 * State condition where liquid and vapor coexist simultaneously within certain space

Saturated condition

3.20 * Describe subcooled matter

Any liquid at temperature lower than saturation temperature

3.21 * List steps in determining number of degrees liquid refrigerant has been subcooled

1. Find temperature at which refrigerant is condensing.
2. Find temperature of the refrigerant as it leaves condenser.
3. Condensing temperature minus leaving temperature equals degrees subcooling at the condenser.

3.22 * State what determines saturated temperature of refrigerant

Pressure under which it is placed

3.23 * Describe way to determine vapor pressure exerted at specific saturated temperature of refrigerant

If temperature of refrigerant is known, information may be found on pressure/temperature chart.

3.24 * Discuss superheat

1. Heat added to a vapor after total vaporation
2. Usually measured in °F
3. Changes properties of refrigerants
4. May be found by:
   A. Finding the evaporating temperature of the refrigerant
   B. Finding the temperature of the refrigerant as it leaves the evaporator
   C. Evaporating temperature minus leaving temperature equals degrees superheat at the evaporator.

3.25 * Solve problems involving saturation, superheat, and subcooling

As assigned and evaluated by instructor

EXAMPLES:
1. Determine saturation temperature of R-22 with pressure of 32.8 PSIG.
2. Determine degrees F of superheat added to vapor given:
   A. R-12 air conditioning system
   B. Suction pressure of 27 PSIG
   C. Remote temperature bulb temperature of 38°.

3.26 * Determine conditions of refrigerant

1. Saturated, superheated, and subcooled
2. Also determining number of degrees of subcooling and superheating

3.27 * List pressure formulae

1. PSIG + 14.7 = Lbs. per PSIA sq. in. absolute
2. Absolute pressure = 14.7 - (in. hg. x .491)

3.28 * Convert pressures

1. PSIA to PSIG and vice versa
2. As assigned and evaluated by instructor

3.29 * State lb./sq. in. absolute in 1 in. of mercury vacuum

.491

3.30 * Read pressures in gauge absolute and inches of mercury, and observe effects of pressure

As assigned and evaluated by instructor

3.31 State type of gauge most used in refrigeration industry

Bourdon

3.32 * List instruments used for more accurate measurement of negative pressures

1. Mercury manometer
2. Electric vacuum gauge

3.33 * Describe expression of pressures related to atmospheric pressures

1. Above: As positive pressures
2. Below: As inches of mercury vacuum

3.34 * List the 4 refrigerant conditions pressure affects

1. Boiling point
2. Density of liquid
3. Volume of vapor
4. Heat content

3.35 * Solve problems involving effects of pressure

As assigned and evaluated by instructor

EXAMPLES:
1. Determine vapor volume of R-12 at 10 and 29.335 PSIA.
2. State equal pressure in absolute of 18 in. hg.

3.36 * State whether or not condensing pressure and temperature must be above ambient conditions to remove heat from condenser absorbed in evaporator

Condensing temperature must be above ambient conditions.

3.37 * List laws involving gases

1. Charles' Law: $Po \times In = Pn \times To$
2. Boyle's Law: $Po \times Vo = Pn \times Vn$
3. Dalton's Law: Total Pressure = Sum of Partial Pressures
4. Gas Law (Charles' + Boyles'): $\frac{Po \times Vo}{To} = \frac{Pn \times Vn}{Tn}$
5. Perfect Gas Equation: $PV = WRT \frac{1545.3}{\text{Molecular Weight}}$
6. Gay-Lussac's Law: Volume is directly proportional to absolute temperature.

3.38 * List 3 rules involving gases

1. Volume and temperature change are proportional if pressure remains constant.
2. Volume and pressure are inversely proportional if temperature remains constant.
3. Changes in temperature and pressure are directly proportional if volume remains constant.

3.39 * Solve problems involving gas laws and the perfect equation

As assigned and evaluated by instructor

EXAMPLES:
1. Determine new volume of 10 cu. ft. of gas under constant pressure changed from 40°F to 290°F.
2. Determine new temperature of 3 cu. ft. of gas at 20 PSIG and 150°F changed to 5 cu. ft. container.

3.40 * Solve problems dealing with gas laws

As assigned and evaluated by instructor

UNIT: Compression System of Refrigeration

3.41 * State factor determining whether to charge with vapor or with liquid

Amount of refrigerant held by system--Large systems are usually charged with liquid.

3.42 * State what determines point in system where refrigerant will actually enter

Whether system is to be charged with refrigerant in gaseous or liquid form

1. Low side, compressor on: Charge with gas.
2. High side, compressor off: Charge with liquid.

3.43 * List the 4 basic methods of determining whether proper amount of refrigerant is being introduced

1. Charging by sight glass
2. Charging by pressures
3. Weighing charge
4. Using frost line

3.44 * Discuss charging by superheat

1. For systems using capillary tube as metering device
2. Involves use of pressure temperature chart
3. Involves establishing high ambient head pressure condition
4. Very effective method

3.45 * Solve problems involving charging without a charging cylinder

As assigned and evaluated by instructor

EXAMPLE: State superheat at compressor in operating R-12 system with:

1. Suction pressure reading of 37 PSIG
2. Temperature of suction line at compressor of 50°F.

3.46 * Explain why service drum should never be turned upside down when charging through low side

1. Liquid refrigerant would pass through valves of compressor.
2. Valves are designed to pump refrigerant gas only.

3.47 * State cause of frost on service drum and way to speed up charging process

1. Frost is caused from lowered pressure in drum. When refrigerant changes to a gas in a drum, it absorbs heat from remaining refrigerant which lowers temperature and pressure of drum.
2. Charging process may be speeded up by placing drum in a bath of warm water.

3.48 * List 4 precautions to take when charging without a cylinder

1. Handle the refrigerant cylinders carefully. Do not drop them.
2. Do not heat the cylinders with a torch.
3. Use a strap or chain to secure cylinders when transporting them, even on the cart.
4. Avoid refrigerant contact with the skin.
5. Do not inhale the refrigerant. Use only in a well ventilated area.
6. Secure large cylinders to a wall or bench.
7. Replace the cylinder cap when not using the cylinder to protect the valve.
8. Do not mix refrigerants.
9. Do not carry the refrigerant drum by the valve.
10. Remove the valve when discarding disposable cylinders.
11. Open the service valve on line punctures very slowly to avoid oil loss.
12. Do not front seat the high-side service valve with the compressor operating.
13. Watch head pressure very closely during charging process.
14. Be sure to select correct refrigerant.
15. Do not allow liquid refrigerant to enter compressor from suction side of system.

3.49 * Install liquid charge

1. Using R-12 service drum
2. Following directions of instructor
3. Figuring amount of refrigerant used
4. Safely and cleanly

3.50 * Install vapor charge

1. Using R-12 service drum
2. Following directions of instructor
3. Figuring amount of refrigerant used
4. Safely and cleanly

UNIT: Refrigerants

3.51 * Define terms as they relate to refrigerants

1. Refrigerant
2. Secondary refrigerant
3. Refrigerant effect
4. Net refrigerating effect (N.R.E.)
5. Pressure
6. Temperature
7. Volume
8. Density
9. Enthalpy
10. Entropy
11. Miscibility
12. Leakage tendency
13. Odor
14. Moisture reaction
15. Leak detection
16. Toxicity
17. Flammability
18. Economics
19. Thermodynamic properties
20. Physical properties
21. Saturated vapor
22. Superheat

3.52 Identify refrigerants by color code

1. From refrigerant drums
2. Including:
   A. R-11: Orange
   B. R-12: White
   C. R-13: Pale blue
   D. R-22: Green
   E. R-113: Purple
   F. R-114: Dark blue
   G. R-500: Yellow
   H. R-502: Orchid
   I. R-503: Aqua marine
   J. R-504: Tan
   K. R-717: Silver

3.53 * List 4 toxic refrigerants

1. R-717
2. R-764
3. R-30
4. R-40

3.54 * List 5 flammable refrigerants

1. R-40
2. R-170
3. R-600
4. R-290
5. R-717

3.55 * List 4 nonflammable refrigerants

1. R-11
2. R-12
3. R-22
4. R-30

3.56 * List 10 safety precautions when working with refrigerants

1. Always work in an area with proper ventilation, especially when working on system with a leak.
2. Always check pressures in the system.
3. Check refrigerant R number before charging system.
4. Be sure there are no open flames near system suspected of having a leak if refrigerant is a fluorocarbon.
5. Always check I.C.C. stamp on cylinder to make sure the cylinder is safe.
6. Always wear goggles and gloves when charging or discharging system.
7. Always charge refrigerant vapor into low side of system.
8. Do not spill liquid refrigerant on skin--it can cause frostbite.
9. Make certain refrigerant cylinder is never completely filled with liquid refrigerant.
10. Store refrigerant cylinders in cool, dry place.
11. Never use cylinders for rollers.
12. Never store a refrigerant other than the one on the label in a refrigerant cylinder.
13. Always remember that using cylinders for compressed air is very dangerous.
14. Remember that R-717 and R-764 are very irritating to the eyes and lungs.
15. Remember that refrigerant oil contained in hermatic compressor that has had a burnout may be very acidic.

3.57 * List 4 characteristics/properties of a good refrigerant

1. Have condensing pressure as low as possible and still maintain normal evaporating pressure above atmospheric
2. Maintain small positive pressure on system at all times
3. Have highest possible refrigeration effect
4. Have lowest possible leakage tendency
5. Have least possible odor for nontoxic refrigerants
6. Have least possible toxicity
7. Have least possible moisture absorption capability

NOTE: There is no "best" refrigerant. Each application must be studied thoroughly to determine the refrigerant that will be "better" for the conditions.

3.58 * State what occurs when a halogen refrigerant comes in contact with an open flame

A toxic gas (phosgene) is formed.

3.59 * List 5 secondary refrigerants

1. Water
2. Calcium chloride brine
3. Alcohols
4. Glycols
5. R-11
6. Others according to instructor

3.60 * State boiling points of R-22 and R-12

1. R-22: -41° at atmospheric pressure
2. R-12: -22° at atmospheric pressure

3.61 * State formula for cu. ft. per minute per ton

Number of lbs. per minute per ton of refrigerant x Specific volume of refrigerant = Cu. ft. per minute per ton

3.62 * List 6 characteristics of refrigerants

1. Increasing pressure on a liquid increases boiling temperature.
2. Decreasing pressure on a liquid lowers boiling temperature.
3. The greater the temperature difference, the faster the heat flows.
4. Changing the temperature surrounding drum of refrigerant changes pressure inside drum.
5. Lowering pressure on drum of refrigerant lowers boiling point of refrigerant inside drum.
6. Different refrigerants have a different latent heat of vaporization or condensation at the same temperature.

3.63 Solve simple refrigerant problems

1. As assigned and evaluated by instructor
2. Involving:
   A. Volume
   B. Density
   C. Refrigerating effect

EXAMPLES:
1. What is volume of R-12 vapor at 50°F?
2. What is density of R22 liquid at 150°F?
3. What is net refrigerating effect of R502 at -20°F?

3.64 * Find points in system where refrigerant is saturated and superheated

1. Using thermometers and gauges
2. As assigned and evaluated by instructor

3.65 * Select proper refrigerant for system

1. As assigned and evaluated by instructor
2. Considering:
   A. Type of compressor
   B. Temperature of evaporator
   C. Load on system

EXAMPLES:
1. Given the following:
   A. Walk-in freezer
   B. Temperature of 0°F
   C. Heat load of 36,000 BTU/hr.
2. Given the following:
   A. Air conditioning system
   B. Coil temperature of 38°F
   C. Load of 60,000 BTU/hr.

UNIT: Dehydration

3.66 * List the 2 ways moisture may exist in a refrigeration system

1. As free water
2. In solution with refrigerant

3.67 * Describe way to avoid freeze-ups

Maintain moisture content in low temperature systems at very low level

3.68 * Solve problems involving solubility of water in liquid refrigerants

As assigned and evaluated by instructor

3.69 * Describe best place to install moisture indicators

In liquid line

3.70 * List 2 reasons dryers should be located close to expansion valve or capillary tube

1. Drying agents are more effective at low temperature.
2. Appreciable amount of time is required for dryer to remove maximum amount of water.

3.71 * List 8 sources of contamination

1. Air
2. Anti-freeze agents
3. Water
4. Soldering flux
5. Chlorinated solvents
6. Red iron oxide
7. Black iron oxide
8. Red copper oxide
9. Black copper oxide
10. Metal chips and dirt

3.72 * List 5 harmful effects of contaminants

1. Sludging
2. Corrosion
3. Copper plating
4. Acids
5. Freeze-ups

3.73 * List 4 major causes of corrosion

1. High operating temperatures
2. Soldering fluxes
3. Methyl alcohol
4. Poor brazing practices

3.74 * Describe way to remove contaminants

1. Flush system with clean, dry refrigerant.
2. Apply evacuation process.

3.75 * List 4 factors determining time required to remove water and air

1. Size of system
2. Amount of liquid water in system
3. Capacity of vacuum pump
4. Size of connecting lines

3.76 * State gauge recommended for following course of evacuation

Thermocouple micron-vacuum-gauge meter

3.77 * Explain need for vacuum pump with deep vacuum capabilities when evacuating refrigeration system

So vacuum is equal to pressure lower than vapor pressure of water

3.78 * State preferred evacuation method considering time and efficiency

Triple evacuation

3.79 * Solve problems involving Vacuum Steam Table

As assigned and evaluated by instructor

EXAMPLE: What must ambient temperature be to properly evaluate system at 29" Hg.?

3.80 * Select correct drying methods

For examples assigned by instructor

3.81 * Evacuate system using mercury manometer

To 29.8 inches of mercury

3.82 * Evacuate system using thermocouple vacuum meter

5000 microns

3.83 * Install purge charge

Of 5 to 15 PSIG

3.84 * Describe the 2 types of hermetic motor burn-outs

1. Spot burn-outs: Charring of windings confined to one relatively small spot and remainder appears to be bright and clean
2. Cook-out: Practically entire winding charred

3.85 * Describe way to determine extent of burn-out in welded hermetic motor

1. Release some gas and smell it.
   A. Spot: Slightly burned odor
   B. Cook-out: Very pungent burned odor
2. Check oil color or test with acid test kit.
   A. Little or no discoloration of oil, pass acid test
   B. Oil discolored by sludge, fail acid test

3.86 * Discuss causes of burn-outs

1. Spot burn-out
   A. Insulation defect
   B. Abrasion damage
   C. Installation damage
2. Cook-out
   A. Welded contactor
   B. High motor winding temperatures

3.87 * List 5 products of decomposition

1. Moisture
2. Acid
3. Soot
4. Varnish
5. Hard carbon

3.88 * List the 2 most difficult contaminants to remove and the best way to do so

1. Varnish and hard carbon
2. Tear-down and manual cleaning

3.89 * Discuss use of suction line filter-dryer in cleaning system

1. Very useful in cleaning system after burn-out
2. Filtering ability usually good
3. Easier to apply in tight applications
4. Must avoid excessive pressure drops due to plugging

3.90 * Discuss the 2 basic methods of cleaning a system after a burn-out

1. Flushing
   A. Involves removal of all items restricting liquid circulation
   B. Requires at least 24 hours of flushing
   C. Disadvantages
      1) Refrigerant charge blown
      2) Requires considerable labor in piping
      3) Requires flushing cart
      4) High down-time
      5) Cleans only when system not in operation
2. Operating
   A. Simple
   B. Refrigerant saved
   C. Less down-time
   D. Clean-up accomplished during operation
   E. Progress of clean-up measurable by oil sample comparisons or acid test kit

3.91 * State most important thing to do before replacing compressor motor after burn-out

Determine cause of burn-out, so it does not occur again.

3.92 * List probable cause(s) of burn-out in actual unit

As evaluated by instructor

3.93 * Describe required clean-up action

As evaluated by instructor

3.94 * Determine if refrigerant and/or oil can be salvaged

As evaluated by instructor

UNIT: Heat Calculations

3.95 * Describe heat

1. Form of energy
2. Cannot be destroyed
3. Always flows from hot to cold

3.96 * List the 3 ways heat moves, and give example of each

1. Conduction: Heat moving through a steel rod
2. Convection: People being warmed by a furnace using air as a medium
3. Radiation: Sun shining on the earth through the vacuum of space

3.97 * State exactly what radiation heats

The objects themselves, not the air between them

3.98 * Determine direction of heat flow

As assigned and evaluated by instructor

3.99 * Identify methods of heat transfer

1. From variety of different sources
2. As assigned and evaluated by instructor

3.100 * List 3 environmental factors affecting human comfort

1. Air motion
2. Relative humidity
3. Temperature difference

3.101 * Define terms

1. U factor
2. R value
3. Equivalent temperature difference

3.102 * List 2 examples of internal heat gains

1. Man
2. Lights
3. Electric motors
4. Appliances
5. Steam
6. Water vapor
7. Others according to instructor

3.103 * List 2 examples of external heat gains

1. Solar heat
2. Ventilation
3. Infiltration
4. Others according to instructor

3.104 * State whether or not activity of human body affects its temperature

Yes

3.105 * List the design conditions for Dallas, Texas

1. Summer: 100° dry bulb, 78° wet bulb
2. Winter: 16° above 0°
3. Indoor: 75° dry bulb, 50% relative humidity (ASHRAE)

3.106 * State whether or not color of building surface affects heat gain

Yes

3.107 * State formula for BTU/hr.

Area x ΔT x U factor

3.108 * State number of BTU/hr./watt incandescent light adds

3.4

3.109 * Calculate heat gains

As assigned and evaluated by instructor

EXAMPLES:
1. Given the following:
   A. 10' x 10' wall
   B. U factor of .25
   C. Temperature difference of 15°F
2. Given the following:
   A. Window 6'x 6' on west wall of house in Dallas, TX at 4 p.m. on August 24
   B. Double glass window
   C. Outside temperature 100°
3. Given the following
   A. Room with three 100 watt incandescents and two 40 watt flourescent lamps
   B. Three people
   C. 1/2 h.p. electric motor

3.110 * Calculate co-efficient of heat transfer (U factor)

As assigned and evaluated by instructor

3.111 * Find BTU/hr.

As assigned and evaluated by instructor

EXAMPLE: For wall with temperature difference of 25°F

UNIT: Properties of Air

3.112 * Define terms

1. Relative humidity
2. Dew point temperature
3. Specific density
4. Specific volume
5. Specific heat
6. Dry bulb temperature
7. Enthalpy
8. Saturation point
9. Sensible heat ratio
10. Apparatus dew point
11. Bypass air
12. Standard air
13. Latent heat
14. Specific humidity
15. Sensible heat process
16. Dehumidification
17. Air conditioning
18. Dalton's Law

3.113 * State number of grains of moisture in one lb. of water

7,000

3.114 * State instrument used to measure wet bulb and dry bulb temperatures

Sling psychrometer

3.115 * State which therometer has cotton wick over one end

Wet bulb

3.116 * List the 3 temperatures that will be the same if there is 100% humidity

1. Dry bulb
2. Wet bulb
3. Dew point

3.117 * State at what rate and for how long sling psychrometer should be slung

1. Three to four revolutions per second
2. At least one minute

3.118 * State minimum number of readings needed for accuracy

Three

3.119 * Explain why wet bulb temperature is lower than dry bulb when relative humidity is less than 100%

When the humidity is less than 100%, moisture will evaporate from the wet bulb thermometer lowering its temperature.

3.120 * List steps in use of sling psychrometer

1. Sling instrument three to four revolutions per second for one minute.
2. Record temperatures.
3. Repeat two more times.
4. Average temperatures.

3.121 * List steps in finding relative humidity of air with sling psychrometer

1. Determine wet bulb and dry bulb temperatures.
2. Use scale on side of sling psychrometer.

3.122 * Find unknowns

As assigned and evaluated by instructor

EXAMPLE: Given: 75° dry bulb, 70° wet bulb
Find: Relative humidity using sling psychrometer

3.123 * List basic parts of psychrometric chart

1. Dry bulb temperature
2. Wet bulb temperature
3. Enthalpy
4. Grains of moisture
5. Relative humidity
6. Specific volume
7. Dew point temperature

3.124 * State what process line indicates

Change undergone by air as it is heated or cooled

3.125 * List steps in drawing process line on psychrometric chart

1. Determine wet bulb and dry bulb temperatures.
2. Plot points on chart.
3. Draw line between the two points.

3.126 * Discuss changes in process line

1. If sensible heat only is added or removed, process line is parallel to base of chart.
2. If moisture only is added or removed, process line will move up or down dry bulb line.
3. If both are changed, process line will move at angle from beginning point.

3.127 * Measure and record wet and dry bulb temperatures

1. Inside and outside
2. Entering and leaving air of a coil

3.128 * Determine relative humidity of entering and leaving air

As assigned and evaluated by instructor

3.129 * Draw process lines on psychrometric charts

As assigned and evaluated by instructor

3.130 * Describe where on psychrometric chart A.D.P. is read

At point where process line crosses saturated curve

3.131 * State what enthalpy scale on chart is used to determine

Total heat removed from a volume of air

3.132 * State formula for amount of sensible heat removed at standard air conditions BTU/hr.

60 x C.F.M. of air going over coil x 1.08 x ΔT

3.133 * State formula for amount of latent heat removed at standard air conditions BTU/hr.

60 x C.F.M. of air x .68 x ΔGR.

NOTE: This formula is accurate only when air is at standard condition of 13.34 cu. ft. per lb.

3.134 * State formula for amount of heat removed at other than standard conditions BTU/hr.

$$\frac{\text{CFM} \times 60}{\text{Specific volume}} \times \text{Enthalpy}$$

3.135 * State formula for total heat removed from volume of air

Enthalpy content of entering air of coil = Enthalpy content of air leaving coil

3.136 * Draw sensible heat ratio line of .70 for Dallas design conditions

As evaluated by instructor

3.137 * Find A.D.P.

As assigned and evaluated by instructor

3.138 * Plot psychrometric chart of entering and leaving air

1. Determine total heat removed.
2. Determine amount of sensible heat removed.
3. Determine amount of latent heat removed.

3.139 * Calculate total heat removed from given space in given amount of time

As assigned and evaluated by instructor

3.140 * Describe effect on space if too much latent but not enough sensible heat is removed and vice versa

1. Room will feel warm and dry.
2. Room will feel cold and clammy.

UNIT: Pressure-Enthalpy (Ph) Diagram

3.141 * Define "enthalpy"

Heat content

3.142 * List 10 refrigerant conditions/properties possible to determine with Ph diagram

1. Compression ratio
2. Latent heat of condensation
3. Latent heat of vaporization
4. Net refrigerating effect
5. Heat of compression
6. Amount of refrigerant to be circulated
7. Compressor displacement per ton
8. Compressor power per ton
9. Heat of condensation
10. Effects of liquid subcooling
11. Effects of suction vapor superheating
12. Volume of refrigerant entering compressor
13. Effects of lower head or evaporator pressure
14. Effects of higher head or evaporator pressure

3.143 * State major advantage of Ph diagram over saturation, refrigerant properties, and superheated vapor tables

It provides a graphic way for technician to see refrigeration cycle, its conditions, and problems as a whole rather than as a large number of individual pieces.

3.144 * Label major lines and areas of Ph diagram

1. Saturated liquid line
2. Saturated vapor curve
3. Subcooled (liquid) region
4. Superheated (vapor) region
5. Region of phase change
6. Liquid to vapor path
7. Vapor to liquid path
8. Liquid-vapor mixture area

3.145 * State pressures used on Ph diagram

PSIA

3.146 * Describe how Ph diagram is useful in determining effects of changing refrigerant conditions

Comparison of Ph diagram of present given conditions with diagram showing proposed changes provides clear picture of results of such changes.

3.147 * Draw skeleton of Ph diagram, and identify the 4 processes

As evaluated by instructor

3.148 * Solve problems involving Ph diagrams

As assigned and evaluated by instructor

EXAMPLES:
1. With evaporator pressure (R-12) constant at 40 PSIA, what effect does increasing super heat of vapor entering compressor from 40°F to 65°F have upon size of compressor required to handle load?
2. With evaporator conditions remaining the same, what are the effects of raising condensing pressure?

3.149 * Interpret Ph diagrams

As assigned and evaluated by instructor

EXAMPLES:

1. Given R-12 system with following conditions:
   A. Evaporation temperature: 40°
   B. Condensing temperature: 110°
   C. Temperature of vapor leaving evaporator: 60°
   D. Temperature of vapor entering condenser: 125°
   E. Temperature of liquid leaving condenser: 85°
   F. Temperature of liquid entering metering device: 60°
   G. Temperature of vapor entering compressor: 65°
2. Record:
   A. N.R.E.
   B. Heat of compression
   C. Heat rejected by condenser
   D. Compression ratio
   E. Subcooling done by heat-exchange

OR

1. Given:
   A. Evaporator temperature: 9 PSIG
   B. Suction gas superheated to: 40°F
   C. Condensing temperature: 110°F
2. Record:
   A. Compression ratio
   B. Discharge gas superheat
   C. Discharge gas volume/lb.
   D. Heat of compression per lb. circulated

OR

1. Given:
   A. Refrigerant 12 system operating on simple saturated cycle
   B. Evaporation temperature: 20°F
   C. Vapor leaving evaporator superheated: 20°F
   D. Condensing temperature: 120°F
   E. Liquid subcooled in condenser: 10°F
2. Determine:
   A. Weight of refrigerant circulated per min./ton
   B. Volume cu. ft./min. of vapor compressed/ton
   C. Coefficient of performance
      1) Cooling
      2) Heating
   D. Theoretical horsepower/ton
   E. Heat rejected/hr./ton at condenser

SAFETY TEST

1.-57. Choose the one best answer unless otherwise instructed.

1. Oily rags should be:

   A. Discarded in a wastebasket
   B. Kept in a covered container
   C. Washed and dried
   D. Kept in an open container

2. An operating machine can be left unattended:

   A. For any period of time, as long as everyone is aware it is operating
   B. For two minutes, if operator does not leave the room
   C. For one minute
   D. Never

3. Sharp-pointed tools should be carried:

   A. Pointed toward floor
   B. With two hands
   C. Pointed upward
   D. In a box

4. Oil spots on the floor should be:

   A. Covered until they dry
   B. Washed away with water
   C. Wiped up as well as possible and allowed to dry
   D. Cleaned up completely

5. Damaged tools should be:

   A. Used carefully
   B. Not used at all
   C. Used for light work only
   D. Reported to instructor

6. Hand tools should be stored:

   A. In a toolbox
   B. On a wall panel
   C. In a shed
   D. Face up

7. To pull nails with a hammer:

   A. Pull hammer handle as far as possible.
   B. Grip handle with both hands.
   C. Pull handle to near vertical, and insert a wedge.
   D. Use pliers, never a hammer.

8. A setting hammer is designed for:

   A. Setting nails
   B. Forming and striking sheet metal
   C. Forming heavy metal
   D. Peening metal

9. The longest screwdriver convenient for a job:

   A. Allows greater control and more power than a shorter one
   B. Gives less power than a shorter one
   C. Allows less control than a shorter one
   D. Is not as safe as a shorter one

10. Before using a hammer, inspect the head:

   A. For curvature
   B. For strength
   C. To make sure it is firmly secured to the handle
   D. For weight

11. The furnace burner flame does not burn properly without enough:

   A. Warm water
   B. Combustion air
   C. Return air to the fan
   D. Forced warm air

12. Products of incomplete combustion are a sign of inefficient use of:

   A. The fan
   B. Fuel
   C. Air
   D. Warm water

13. A serious explosion can be caused by:

A. Too much air
B. Not enough air
C. Partially burned raw fuel
D. A leaking flue pipe

14. Combustion air can be supplied to the furnace through:

A. Separate air duct to outside
B. Furnace fan
C. Return air system from house
D. Supply air system

15. A leak in the furnace flue pipe is:

A. A serious safety hazard
B. A sign of good construction
C. Required to minimize pressure buildup
D. A sign of a faulty burner

16. Select the <u>two</u> important actions to be taken when raw unburned gas is detected near a gas appliance or furnace.

A. Turn off the gas.
B. Light a match.
C. Close the windows.
D. Open the windows.

17. One of the safest ways of searching for gas leaks is:

A. A cigarette lighter
B. Matches
C. Soap bubbles
D. The smoke test

18. Select the <u>two</u> actions to be taken when gas odor is detected near a gas furnace that has an electrical spark ignitor.

A. Turn off the electrical power to the furnace.
B. Dampen the ignitor with a wet cloth.
C. Turn up the thermostat.
D. Shut off the gas.

19. How should a furnace flue be installed?

A. Connect the furnace flue to the fireplace flue above the fireplace.
B. Connect the furnace flue to the fireplace flue below the fireplace.
C. Use a separate flue.
D. Connect the furnace flue to the clothes dryer flue.

20. What action should <u>not</u> be taken if an oil furnace is not operating properly and oil is accumulating in the combustion chamber?

A. Shut off all electrical power to the furnace.
B. Remove the fuel oil from the combustion chamber.
C. Strike a match to see how much oil has accumulated.
D. Open the windows and doors.

21. Voltmeters are used to test:

A. Continuity
B. Voltage
C. Amperage
D. Watts

22. Ohmmeters are used to test:

A. Continuity
B. Voltage
C. Amperage
D. Watts

23. Ammeters are used to test:

A. Ohms
B. Voltage
C. Amperage
D. Millivolts

24. To test an unknown voltage, set the voltmeter at:

A. Zero
B. The highest scale
C. The off position
D. 3/4 of the expected voltage

25. An ohmmeter can be used to test:

A. A live circuit
B. A dead circuit
C. Double circuits
D. Batteries

26. For a safe, accurate amperage reading, always attach the ammeter:

A. To a solid object
B. To two wires
C. To a single wire
D. To a drop wire

27. Before working on an electrically operated device, always:

A. Turn off the water.
B. Turn off the power.
C. Stand on a wooden box.
D. Have a helper near.

28. Electrical equipment should be grounded:

A. If it is used in a damp area
B. If the proper tools are available
C. Always
D. Never

29. When attached to a live contact, metal test clips should:

A. Be held off the ground
B. Not touch other metal parts
C. Touch other metal parts
D. Be grounded

30. A torch flame should never be used on pipes containing:

A. Fresh water
B. Air
C. Refrigerants
D. Salt water

31. High heat from a torch in contact with a refrigerant can cause:

A. High efficiency
B. Low efficiency
C. Toxic gases
D. Free oxygen

32. Toxic gases can cause damage to the:

A. Human respiratory system
B. Air supply duct
C. Manifold gauges
D. Return air duct

33. An appropriate gas mask should be available when working on systems containing 100 lbs. or more of:

A. Water
B. Group 2 refrigerants
C. Steam
D. Compressor weight

34. Fusible plugs offer protection to the:

A. Receiver
B. Compressor
C. Coil
D. Refrigerant cylinder

35. A cylinder properly filled with refrigerant is safe:

A. Only at high temperatures
B. Only at moderate temperatures
C. If wrapped in burlap
D. At certain temperatures depending on refrigerant characteristics

36. To change refrigerant from a liquid to a vapor, use:

A. A torch
B. Hot water
C. Warm water
D. Steam

37. Using medium pressure range manifold gauges on high pressure systems will:

A. Give a better reading
B. Damage the gauge mechanism
C. Cause no damage
D. Lower the gauge reading

38. A fusible plug in a refrigerant cylinder softens at:

A. 120°F (49°C)
B. 157°F (69°C)
C. 150°F (66°C)
D. 212°F (100°C)

39. The fusible plug in a refrigerant cylinder melts at:

A. 120°F (49°C)
B. 157°F (69°C)
C. 212°F (100°C)
D. 165°F (74°C)

40. A refrigerant cylinder should never be:

A. Completely filled
B. 1/2 filled
C. Empty
D. 1/4 filled

41. Refill refrigerant cylinders according to:

A. The listed nameplate weight
B. Volume
C. The best estimate of an experienced mechanic
D. Need

42. When changing the refrigerants found in most residential systems, use at a temperature of:

A. 160°F (71°C)
B. 211°F (99°C)
C. 43°F (6°C)
D. 125°F (52°C)

43. Which of the following refrigerant groups is most hazardous?

A. ANSI, Group 1
B. ANSI, Group 3
C. UL, Group 3
D. UL, Group 6

44. To bump a compressor use a:

A. Rubber mallet
B. Rawhide mallet
C. Capacitor
D. Battery

45. The greatest danger in using a headbolt that is too long is:

A. It cannot be tightened adequately
B. It may interfere with compressor operation
C. It may vibrate loose
D. It may be twisted off or stripped easily

46. If the fan motor rain shield is too tight:

A. The motor may overheat.
B. It may rub on the motor.
C. It may not shield the motor properly.
D. It may interfere with the operation of the fan.

47. The direction that a fan motor should rotate is normally indicated on the:

A. Motor housing
B. Pulley
C. Fan shaft
D. Fan housing

48. The compressor shipping plugs should be removed:

A. As soon as the compressor is received
B. Never
C. Just before the piping is installed
D. After the piping is installed

49. Slings for rigging should not be used unless unit has:

A. Two valves
B. Two compressors
C. A purge valve
D. Skids

50. Loosen any shipping bolts, bands, or belts according to the manufacturer's instructions before:

A. Stopping the unit
B. Shipping the unit
C. Installing the unit
D. Starting the unit

51. A loose fan belt will:

A. Slip on its pulley
B. Last longer
C. Run coolly
D. Damage the bearing

52. One and one-half inch deflection of the fan belt when pressed with the finger is:

A. Too tight
B. Too loose
C. Typical
D. Not enough deflection

53. When replacing bearings on a shaft, use:

A. Heavy blows with a heavy hammer
B. Light blows with a heavy hammer
C. Light taps with a light hammer
D. A wrench

54. Damaged or flattened fins on cooling and heating coils can:

A. Sometimes increase efficiency
B. Raise the sound level
C. Decrease efficiency
D. Cause refrigerant leaks

55. Before installing electrical accessories:

A. Turn on the main power switch.
B. Turn off the main power switch.
C. Measure the power box.
D. Look for refrigerant leaks.

56. An outside condensing unit should be located to allow space for:

A. Shrubs
B. A view from a window
C. Refrigerant circulation
D. Servicing

57. When installing refrigerant piping, use:

A. Hooks
B. Long nails
C. Soft nylon rope
D. Vibration isolators

58.-83. Choose the one correct letter from the group on the right.

58. Use tools and machinery only _____
59. All tools should be cleaned _____
60. For maximum safety, be sure hand tools and machines are in a nonoperating position _____
61. Only properly secured clothing should be worn _____
62. Extension cords should be placed _____
63. When using a hand drill _____

A. and neatly stored
B. before cleaning, oiling, adjusting and repairing
C. if they are in good condition
D. where they cannot cause tripping
E. around operating equipment

64. A properly selected screwdriver _____
65. Sharp ferruled connections _____
66. Metal surfaces on tools _____
67. Refrigerant gas can permeate charging hoses and _____

A. fits the slot in the screwhead
B. should be lightly oiled
C. turn the crank with constant, even pressure
D. should be replaced
E. collect under the outer surface

68. Ground a power pack even when it is being repaired _____
69. Before correcting the malfunction, reset a safety switch _____
70. A fused disconnect switch should be installed _____
71. Special care is required when drilling holes _____

A. only once
B. for each power circuit
C. on a workbench
D. in a control box or unit casing

72. The fan should rotate _____
73. Compressors are shipped _____
74. Use a large, open rain shield _____

A. with the shipping plugs in place
B. in the direction of the arrow
C. to prevent motor damage by heat

75. Using an oversized wrench _____
76. Using an undersized wrench _____
77. Using an oversized screwdriver _____
78. An undersized screwdriver _____
79. Oiling gaskets _____
80. A plastic sleeve _____
81. A drill which is too long _____
82. Heavy work gloves _____
83. Loose grommets _____

A. can cause undertightening and leaks
B. protects the joint
C. reduces friction and causes misalignment
D. reduces the possibility of cuts
E. can cause damage to the blade
F. can damage the coils and controls
G. can cause overtightening and damage to the fittings
H. Can cause fan and motor damage
I. will not fit the slot

BASIC PRINCIPLES OF REFRIGERATION

SAFETY TEST

ANSWER KEY

1. B	26. C	51. A	76. A
2. D	27. B	52. C	77. E
3. A	28. C	53. C	78. I
4. D	29. B	54. C	79. C
5. B	30. C	55. B	80. B
6. A	31. C	56. D	81. F
7. C	32. A	57. D	82. D
8. B	33. B	58. C	83. H
9. A	34. D	59. A	
10. C	35. B	60. B	
11. B	36. C	61. E	
12. B	37. B	62. D	
13. C	38. B	63. C	
14. A	39. D	64. A	
15. A	40. A	65. D	
16. A, D	41. A	66. B	
17. C	42. D	67. E	
18. A, D	43. B	68. C	
19. C	44. C	69. A	
20. C	45. A	70. B	
21. B	46. A	71. D	
22. A	47. A	72. B	
23. C	48. C	73. A	
24. B	49. D	74. C	
25. B	50. D	75. G	

4. VAPOR COMPRESSION SYSTEMS

UNITS

Refrigeration Processes and Components

Pressure-Enthalpy (Ph) Diagram

Thermostatic Expansion Valve (TEV)

Capillary Tube

Other Metering Devices

Evaporators

Defrost Methods and Devices

Compressor Types

Reciprocating Compressors

Compressor Capacity

Control and Service of Condensers

Services Valves

Installing Oil Charge

Charging with a Charging Cylinder

UNIT: Refrigeration System Process and Components

4.01 * Define terms

1. Refrigeration
2. Refrigerant
3. Compressor
4. Condenser
5. Evaporator
6. Metering device
7. Liquid line
8. Suction line

4.02 * Identify 4 major components of refrigeration system by name and function

Component	Function
1. Evaporator	1. Place for liquid refrigerant to boil off and absorb heat from medium being cooled
2. Compressor	2. Increase pressure and temperature of low pressure vapor to point vapor can be condensed
3. Condenser	3. Place for high pressure/high temperature refrigerant to condense back to liquid and release heat
4. Metering device	4. Meter proper amount of refrigerant to evaporators and reduce pressure on liquid entering evaporator

4.03 * State formula for calculating compression ratio for compressor

$$CD = \frac{\text{Absolute discharge pressure}}{\text{Absolute suction pressure}}$$

4.04 * List the 2 main types of condensers used in the industry today

1. Air-cooled (Forced or natural draft)
2. Water-cooled

4.05 * List 6 types of metering devices

1. Hand-operated needle valve
2. Low-side float
3. High-side float
4. Automatic expansion valve
5. Thermostatic expansion valve
6. Capillary tube

4.06 * List the 2 places in the system where refrigerant changes states

1. Condenser
2. Evaporator

4.07 * Identify compressor, and calculate compression ratio

Using refrigeration trainer

4.08 * Identify condenser, and observe change in liquid level

1. Using refrigeration trainer
2. Manipulating fan speed control
3. Recording liquid level at each speed

4.09 * Identify evaporator, and observe temperature changes

Using refrigeration trainer

UNIT: Pressure-Enthalpy (Ph) Diagram

4.10 * Define "enthalpy"

Heat content

4.11 * List 10 refrigerant conditions and properties possible to determine with Ph diagram

1. Compression ratio
2. Latent heat of condensation
3. Latent heat of vaporization
4. Net refrigerating effect
5. Heat of compression
6. Amount of refrigerant to be circulated
7. Compressor displacement per ton
8. Compressor power per ton
9. Heat of condensation
10. Effects of liquid subcooling
11. Effects of suction vapor superheating
12. Volume of refrigerant entering compressor
13. Effects of lower head or evaporator pressure
14. Effects of higher head or evaporator pressure

4.12 * State major advantage Ph diagram has over saturation, refrigerant properties, and superheated vapor tables

It provides a graphic way for the technician to see the refrigeration cycle, its conditions, and problems as a whole rather than as a large number of individual pieces.

4.13 * Label major lines and areas of Ph diagram

1. Saturated liquid line
2. Saturated vapor curve
3. Subcooled (liquid) region
4. Superheated (vapor) region
5. Region of phase change
6. Liquid to vapor path
7. Vapor to liquid path
8. Liquid-vapor mixture area

4.14 * State pressures used on Ph diagram

PSIA

4.15 * Explain how Ph diagram is useful in determining effects of changing refrigerant conditions

Comparison of Ph diagram of present given conditions with diagram showing proposed changes provides clear picture of results of such changes.

4.16 * Draw skeleton Ph diagram, and identify the 4 processes

As assigned and evaluated by instructor

4.17 * Solve hypothetical problems involving Ph diagrams

As assigned and evaluated by instructor

EXAMPLES:
1. With evaporator pressure (R-12) constant at 40 PSIA, what effect does increasing super heat of vapor entering compressor from 40°F to 65°F have upon size of compressor required to handle load?
2. With evaporator conditions remaining the same, what are the effects of raising condensing pressure?

4.18 * Interpret Ph diagrams

As assigned and evaluated by instructor

EXAMPLES:

1. Given R-12 system with following conditions:
   A. Evaporation temperature: 40°
   B. Condensing temperature: 110°
   C. Temperature of vapor leaving evaporator: 60°
   D. Temperature of vapor entering condenser: 125°
   E. Temperature of liquid leaving condenser: 85°
   F. Temperature of liquid entering metering device: 60°
   G. Temperature of vapor entering compressor: 65°
2. Record:
   A. N.R.E.
   B. Heat of compression
   C. Heat rejected by condenser
   D. Compression ratio
   E. Subcooling done by heat-exchanger

OR

1. Given:
   A. Evaporator temperature: 9 PSIG
   B. Suction gas superheated to: 40°F
   C. Condensing temperature: 110°F
2. Record:
   A. Compression ratio
   B. Discharge gas superheat
   C. Discharge gas volume/lb.
   D. Heat of compression per lb. circulated

OR

1. Given:
   A. Refrigerant 12 system operating on simple saturated cycle
   B. Evaporation temperature: 20°F
   C. Vapor leaving evaporation superheated 20°F
   D. Condensing temperature: 120°F
   E. Liquid subcooled in condenser 10°F
2. Determine:
   A. Weight of refrigerant circulated per min./ton
   B. Volume cu. ft./min. of vapor compressed/ton
   C. Coefficient of performance
      1) Cooling
      2) Heating
   D. Theoretical horsepower/ton
   E. Heat rejected/hr./ton at condenser

4.19 * Construct Ph diagram

1. Given operating conditions
2. Including:
   A. A saturated cycle
   B. A subcooled cycle
   C. A superheated cycle
   D. A pressure-drop cycle
3. With 90% accuracy

4.20 * Construct and interpret Ph diagram

1. Given operating refrigeration system and all necessary tools and equipment
2. Determining:
   A. Net refrigerating effect
   B. Compression ratio
   C. Volume of vapor entering compressor
   D. Heat rejected in condenser
   E. Effects of pressure drops
   F. Heat of compression
   G. Co-efficient of performance
3. With at least 90% accuracy

4.21 * Choose better set of conditions

1. Using procedure above
2. Comparing initial and changed conditions of co-efficient of performance
3. Without error
4. As assigned and evaluated by instructor

UNIT: Thermostatic Expansion Valve (TEV)

4.22 * Describe TEV

1. Involves three pressures
   A. Bulb: Tries to open valve
   B. Evaporator: Works in closing direction
   C. Spring: Works in closing direction
2. Keeps evaporator as nearly completely saturated as possible under all load conditions
3. Requires external equalizer on large evaporators with large pressure drop
4. Normally possible to select expansion valve on basis of evaporator temperature range
   A. G: +50°F to +30°F
   B. C: +35°F to 0°F
   C. Z: 0°F to -40°F
   D. X: -40°F to -100°F
   E. L: Used only for unusual applications beyond scope of G, C, Z, or X charges
5. Controlled by superheat

4.23 * Identify parts of TEV

1. From picture and actual disassembled valve
2. Parts
   A. Seal cap
   B. Bottom cap assembly
   C. Adjusting stem
   D. Spring guide
   E. Spring
   F. Pin carrier
   G. Pin
   H. Seat
   I. Strainer
   J. Inlet
   K. Body
   L. Outlet
   M. Push rods
   N. Thermostatic element

4.24 * State name of pressure to adjust to change superheat on TEV

Spring

4.25 * State what L on top of sporlan-type expansion valve signifies

Liquid charge bulb

4.26 * Describe result of excessive flash gas in TEV

Reduced system capacity

4.27 * Describe where external equalizer should be attached to evaporator

Downstream from bulb

4.28 * State whether or not external equalizer should be capped

No

4.29 * List 3 types of bulb charges

1. Liquid
2. Gas
3. Cross

4.30 * Select bulb charges

1. Temperature of -60°F
2. Temperature of -5°F
3. Air conditioning system

4.31 * List advantages and disadvantages of the 3 bulb charges

1. Liquid
   - A. Advantages
     1) Always charged with enough liquid so control of valve is at bulb at all temperatures
   - B. Disadvantages
     1) Initial floodback and overload of compressor motor during pull down possible
     2) No anti-hunt features
2. Gas
   - A. Advantages
     1) Maximum operating pressure during running cycle
     2) Rapid pull down at start up
     3) Anti-hunt features
   - B. Disadvantages
     1) Control of valve leaves bulb if diaphragm case gets colder than bulb

3. Cross
   A. Advantage
      Works to eliminate or control hunting
   B. Disadvantage
      Limited to low temperature applications

4.32 * List 3 advantages of C, Z, or X valve

1. Reduce load on compressor during pull down, and provide for quick pull down during each cycle
2. Prevent floodback to compressor
3. Assist in closing valve during off cycle regardless of warm bulb location
4. Maintain control of valve at bulb despite pre-cooled liquid
5. Minimize valve hunting

4.33 * List 2 advantages of sporlan flowmaster type G

1. Less sensitive to changes in superheat
2. Closes quickly when small amount of liquid refrigerant passes bulb

4.34 * List steps to take when problems with TEV are suspected

1. Make systematic analysis.
2. Use instruments to measure suction pressure and superheat.
3. Analyze next steps using results of measurements.
4. Try possible solutions in systematic fashion.
5. Adjust valves carefully, but not unnecessarily.
6. Check valve size.
7. Disassemble TEV, make necessary repairs, and reassemble and replace.

NOTE: Correctly installed TEV seldom needs service.

4.35 * Describe the 3 conditions an analysis will probably show

1. Low suction pressure and high super heat
2. Low suction pressure and low super heat
3. High suction pressure and low super heat

4.36 * List 3 possible causes of low suction pressure and high super heat

1. Moisture
2. Dirt or wax
3. Undersized valve
4. High super heat adjustment
5. Gas charge condensation
6. Dead thermostatic element
7. Wrong thermostatic charge
8. Low refrigerant charge
9. External equalizer location
10. Restricted external equalizer
11. Evaporator pressure drop with no external equalizer
12. Liquid line flash gas
13. Low pressure drop across valve

4.37 * List 3 possible causes of low suction pressure and low super heat

1. Low load on evaporator
2. Poor air distribution over evaporator
3. Poor refrigerant distribution through evaporator
4. Improper compressor evaporator balance
5. Oil clogged evaporator
6. Flow from one expansion valve affecting another bulb

4.38 * List 3 possible causes of high suction pressure and low super heat

1. Oversized valve
2. Expansion valve seat leak
3. Low super heat adjustment
4. Wrong thermostatic charge
5. Improper bulb and installation
6. Bad compressor--low capacity
7. Moisture
8. Wax or dirt
9. Incorrectly located external equalizer

4.39 * List 3 possible causes of floodback in evaporator during start up

1. Oversized valve
2. TEV seat leak
3. Slow super heat adjustment
4. Wrong thermostatic charge
5. Improper bulb installation
6. Compressor discharge valve leak
7. Solenoid valve seat leak
8. Compressor in cold location
9. Suction line in cold location
10. Evaporator free draining to compressor

4.40 * State first correction to try when system is hunting or cycling and flooding back to compressor at same time

Be certain that bulb is clean and tight to suction line.

4.41 * Define terms

1. Untrapping TEV bulb
2. Systematic analysis of system when troubleshooting
3. Maximum operating pressure (M.O.P.)

4.42 * State what discolored parts of TEV indicate

Evidence of moisture or acid in system

4.43 * List steps in determining super heat

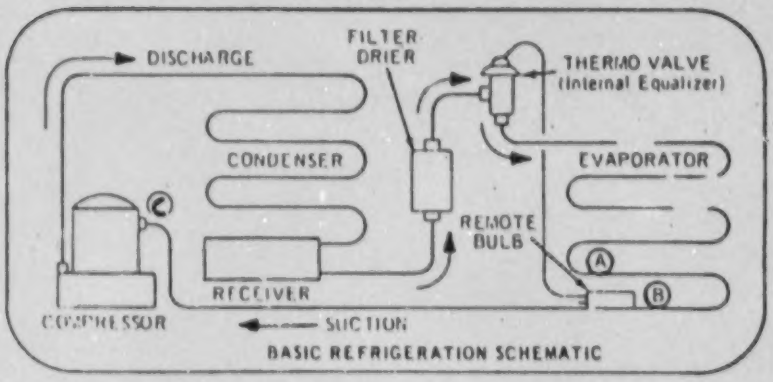
1. Measure temperature of suction line at point where bulb is clamped.
2. Obtain suction pressure in suction line at bulb location.
3. Convert pressure to saturated temperature at evaporator using temperature chart.
4. Subtract temperature obtained in Step #3 from that in Step #1. The temperature difference is the amount of super heat.

4.44 * Solve problems involving super heat

As assigned and evaluated by instructor

EXAMPLE: Determine superheat using drawing below.

Given: Point B: 57°F
Point B: 76 PSIG
R-22 system



BASIC REFRIGERATION SCHEMATIC

4.45 * Describe results of conditions affecting TEV's

1. Effect on super heat of increase in spring pressure on TEV: Increases super heat
2. Loss of charge in TEV bulb:
   A. Starved evaporator
   B. Low suction pressure
   C. High super heat
3. Clogged strainer on TEV: Same as #2

4.46 * State amount of super heat usually allowed on air conditioning system without affecting evaporator

As high as 15°F

4.47 * Describe size of turn of adjustment stem when adjusting for correct super heat

No more than one turn of stem at a time

4.48 * State suggested time intervals between TEV adjustments for super heat

As much as 30 minutes may be required.

4.49 * Disassemble and reassemble TEV

1. Identifying parts
2. Cleaning parts
3. Inspecting parts for wear
4. Replacing worn or defective parts
5. Without damage to any part of valve

4.50 * Install TEV

1. Selecting correct size
2. Using back up wrenches on lines

4.51 * Adjust super heat

1. According to manufacturer's and/or instructor's specifications
2. ±1°F

UNIT: Capillary Tube

4.52 * Describe capillary tube

1. Simplest metering device
2. Consists of fixed length of small diameter tubing installed between condenser and evaporator or between liquid line and evaporator
3. Acts to resist or meter flow of liquid refrigerant from condenser to evaporator
4. Maintains required operating pressure differential between condenser and evaporator
5. Suction pressure lowered and condensing pressure raised by too much restriction
6. Flow capacity greater than pumping capacity where there is not enough resistance
7. Does not stop flow of refrigerant during off cycle
8. Has several advantages
   A. Compressor starts in unloaded condition.
   B. Need for receiver tank is eliminated.
   C. System allows use of low starting torque motor to drive compressor.
   D. There is no wear to parts through the years.
9. Should not be used with open-type compressor
10. Should never be used without adequate strainer at inlet

4.53 * Explain why capillary tube is known as "critical charged system"

1. When compressor cycles off, high and low side pressures equalize through open capillary tube, and any residual liquid in condenser passes to low pressure evaporator where it remains until compressor cycles on again. Possible feedback.
2. Refrigerant charge should be the minimum which will satisfy requirements of evaporation while maintaining liquid seal in condenser at entrance to capillary tube.

4.54 * Describe results of bonding capillary tube to suction line

1. Provides heat transfer relationship between capillary tube and suction line
2. Minimizes formation of flash gas in tube

4.55 * List steps in cleaning restricted capillary tube

1. Remove charge from unit.
2. Disconnect cap tube at both ends if possible.
3. Attach to cap tube pump.
4. Apply as much pressure as needed to remove restriction.
5. Replace filter.
6. Connect cap tube.

4.56 * Clean capillary tube

1. With no damage
2. Removing all restrictions

UNIT: Other Metering Devices

4.57 * State purpose of metering device

Control amount of refrigerant flowing into evaporator so load is in balanced condition allowing refrigerant vapor to leave evaporator in superheated state

4.58 * Identify metering devices by name and special features

Device	Features
1. Hand-operated expansion valve	1. Has needle and seat to control flow
2. Automatic expansion valve	2. A. Maintains constant pressure in evaporator and attempts to maintain constant temperature too B. Should be used in systems with constant load on evaporator C. Used on items such as water fountains and small water chillers D. Has bypass or bleeder part between needle and seat
3. Low-side float	3. Used widely in low-temperature liquid-cooling systems using ammonia, such as ice plants Almost always used with flooded evaporator
4. High-side float	4. Used on systems with critical charge of refrigerant Allows liquid refrigerant to flow to evaporator at same rate as it is being condensed

4.59 * List metering devices in which flash gas might occur

All metering devices

4.60 * Disassemble and reassemble automatic expansion valve

1. Identifying all parts
2. Without damage to any valve parts

4.61 * Observe operating automatic expansion valve

1. With set of gauges installed
2. Adjusting evaporator pressure to 38 PSIG
3. Noticing constant pressure on evaporator under all load conditions

UNIT: Evaporators

4.62 * List the 2 basic types of evaporators

1. Dry or direct expansion
2. Flooded

4.63 * List 3 advantages of dry or direct expansion evaporators

1. No provision for recirculation of liquid or gas needed
2. No separation line between liquid and gas needed
3. May be fed from either top or bottom

4.64 * List the 3 classifications of evaporator surfaces

1. Bare pipe
2. Finned tube
3. Plate

4.65 * List an advantage of dry expansion chillers

1. Take smaller refrigerant charges
2. Assure positive oil return to compressor
3. Minimize posibility of damage to chiller in event of freeze-up

4.66 * Solve problems involving evaporators

1. As assigned and evaluated by instructor
2. Involving:
   A. Amount of heat air must give up to refrigerant
   B. Leaving temperature
   C. Leaving pressure

4.67 * State which fluid flows through tubes of direct expansion chiller

Refrigerant

4.68 * List the 2 most often used secondary refrigerants

1. Water
2. Brine

4.69 * Identify evaporators

1. From actual evaporators provided by instructor
2. According to type and surface classification

4.70 * Measure and record ΔT of air over evaporators and liquid chillers

1. Using three thermometers
2. As evaluated by instructor

4.71 * Adjust liquid flow rate

1. Using operating evaporator with variable pumping capacity, thermometer, and set of gauges
2. To obtain:
   A. ΔT: 5°, ±1°
   B. ΔT: 7°, ±1°
   C. ΔT: 10°, ±1°

UNIT: Defrost Methods and Devices

4.72 * State cause and result of ice forming on evaporator

1. Operating at temperature below 32°F
2. Loss of evaporator capacity

4.73 * List the 5 most common methods of defrosting

1. Off cycle
2. Hot gas
3. Time-initiated/temperature-terminated defrost
4. Time-initiated/pressure-terminated defrost
5. Electric

4.74 * Identify and list advantages and disadvantages of defrost methods of 3 different units

As assigned and evaluated by instructor

4.75 * Describe electric defrost systems

1. Use resistive heating elements to melt frost from evaporator
2. Usually time-initiated
3. May be terminated by time, pressure, or temperature
4. Temperature-initiated

4.76 * List functions of bimetal switch

1. Insure evaporator does not go beyond predetermined temperature
2. Control evaporator fan motor

4.77 * Describe hot-gas defrost system

1. Uses hot-gas discharge from compressor to melt frost from evaporator
2. Uses re-evaporator to evaporate liquid refrigerant condensed in evaporator during defrost
3. Uses reverse cycle defrosting
4. Hot-gas forced backwards through evaporator in two-pipe system
5. Requires compressor to run during defrosting

4.78 * Describe Vapot

Combination suction line, liquid trap, and heat exchanger

4.79 * Adjust hot-gas defrost system

1. As assigned and evaluated by instructor
2. Drawing pictorial and flow chart of system
3. Labeling component parts

UNIT: Compressor Types

4.80 * Identify compressors

1. From pictures and actual samples
2. Types
   A. Reciprocating
      1) Open
      2) Serviceable hermetic
      3) Welded hermetic
   B. Rotary
      1) Rotating vane
      2) Stationary vane
   C. Centrifugal
3. Using correct nomenclature

4.81 * Describe difference between serviceable and welded hermetic compressors

Serviceable can be serviced in the field, and the welded cannot.

4.82 * Identify compressors according to features

1. Blades stationary or rotate with motor: Rotary
2. Used on large tonnage systems: Centrifugal
3. Has shaft extending through housing: Open reciprocating
4. Has pistons: Reciprocating
5. Vanes move with rotor: Rotating vane

4.83 * State wearing parts of centrifugal compressor

Bearings

4.84 * List basic components of reciprocating compressor

1. Piston
2. Cylinder
3. Crank shaft
4. Connecting rod
5. Valve plate

4.85 * Describe way hermetically sealed compressor is driven

Direct drive from motor

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4.86 * List the 2 components totally enclosed in fully hermetic system

1. Compressor
2. Motor

4.87 * State where lubrication is needed in centrifugal compressor

Bearings

UNIT: Reciprocating Compressors

4.88 * List the 4 types of seals most used in the industry today

1. Packing glan
2. Stationary bellows
3. Diaphragm
4. Rotary

4.89 * List the 2 general types of lubrication systems used on reciprocating compressors

1. Splash
2. Pressure

4.90 * Identify components of reciprocating compressor

1. From pictures and actual compressor
2. Components
   A. Crankshaft
   B. Eccentric
   C. Connecting rod
   D. Piston
   E. Piston rings
   F. Cylinder
   G. Valve plate
   H. Crankshaft seal
   I. Suction service valve
   J. Exhaust service valve
   K. Crankshaft

4.91 * Identify parts of reciprocating compressor

1. As assigned and evaluated by instructor
2. Using parts list and pictures

4.92 * State type of reciprocating compressor requiring mechanical shaft seal

Open

4.93 * Describe way all refrigeration compressor valves are opened and closed

In response to pressure differentials caused by changes in cylinder pressure

4.94 * State locations of the 2 types of piston rings

1. Compression: Upper
2. Oil: Lower

4.95 * State what compressor valves are usually made of

Spring steel

4.96 * List 3 guidelines for disassembling and assembling compressors

1. Keep work area clean.
2. Keep all parts clean.
3. Follow manufacturer's step-by-step procedures.

4.97 * Disassemble compressor

1. Completely
2. Labeling component parts

4.98 * Inspect component parts

1. For wear
2. Listing those not meeting manufacturer's specifications

4.99 * Assemble compressor

1. According to manufacturer's directions
2. Without damage to compressor
3. Making gaskets where required
4. Making completely operational

UNIT: Compressor Capacity

4.100 * State general reason for compressor control

To regulate capacity of machine to match changing load conditions

4.101 * List the 4 most common methods of controlling compressor capacity

1. Variable speed and motor
2. Hot gas bypass
3. Cylinder bypass
4. Cylinder unloading

4.102 * State formula for calculating piston displacement of a compressor

Piston Displacement = $\frac{D^2 \times L \times N}{4}$ (of cylinders)
(always in cu.in.)

4.103 * Solve problems involving piston displacement of a compressor

As assigned and evaluated by instructor

EXAMPLE: Find piston displacement (in cu. in./min. and cu. ft./min.) of two-cylinder compressor rotating at 1,450 r.p.m. with cylinder diameter of 2.5 ins. and length of stroke 2 ins.

4.104 * Define terms

1. Cylinder clearance
2. Mechanical design factors
3. Compression ratio
4. Liquid slugging

4.105 * List 4 application factors that vary compressor capacity

1. Rpm of drive motor
2. Suction psi
3. Discharge psi
4. Type of refrigerant

4.106 * State formula for calculating CFM compressor must have for certain load

$$CFM = \frac{\text{Btu/hr.}}{\text{NRE x Density of vapor x Efficiency Factor x 60}}$$

4.107 * Solve problems involving CFM

As assigned and evaluated by instructor

EXAMPLE: Find CFM given:
1. Load of 36,000 Btu/hr.
2. Condensing temperature of 100°F
3. Evaporator temperature of 36°F
4. Gas entering compressor at 50°F

4.108 * Identify types of compressor capacity control

From variety of compressors provided by instructor

4.109 List factor affecting capacity control for 2 compressors

1. Listing factor individually for each compressor
2. Stating whether each factor is mechanical or application

4.110 * Describe effect of clearance volume on compressor capacity

Reduces compressor capacity

UNIT: Control and Service of Condensers

4.111 * List the 2 basic media to which condensers reject their heat

1. Air
2. Water

4.112 * List the 3 types of condensers

1. Air-cooled (natural or forced draft)
2. Water-cooled
3. Evaporative

4.113 * List the 4 basic types of water-cooled condensers

1. Double pipe
2. Open vertical shell and tube
3. Horizontal shell and tube
4. Shell and coil

4.114 * List the 2 major temperature guidelines for condensers

1. Condensing medium must always be at lower temperature than refrigerant it is condensing.
2. Heat given up by refrigerant in condenser must equal heat picked up by condensing medium.

4.115 * Describe disadvantage of double pipe condenser

Water coil cannot be easily cleaned.

4.116 * State where natural draft air-cooled condenser is most likely found

Household refrigeration

4.117 * State type of system on which vertical shell and coil condenser might be found

Small installations up to approximately 10 tons

4.118 * State types of fans used with forced air condensers

1. Centrifugal
2. Propeller

4.119 * Solve problems involving condensers

As assigned and evaluated by instructor

EXAMPLES:
1. Find leaving pressure of R-12 gas given:
   A. Entering condenser at 116.9 PSIG, 100°F
   B. Leaving condenser at 80°F.
2. Find leaving temperature given:
   A. 10 lbs. refrigerant passing through condenser, giving up 20 Btu's heat/lb.
   B. 10 lbs. water passing through at same time with entering temperature of 80°F.

4.120 * State factor determining capacity of evaporative condenser

Relative humidity

4.121 * State variety of most heat removed from refrigerant in condenser

Latent

4.122 * Service malfunctioning forced draft condenser

Restoring system to normal operation

4.123 * Determine Btu/hr. being rejected by water-cooled condenser

1. Using gauges and thermometers
2. With at least 90% accuracy

4.124 * Set control device

1. Of system with water regulating valve and head pressure controller
2. With head pressure determined by instructor according to system

UNIT: Service Valves

4.125 * Discuss line taps

1. Solder-on valve
   A. Popular line service valve
   B. Provides rapid access to system with minimum refrigerant loss on disconnection
2. Clamp-on valve (for temporary service only)

4.126 * Identify and list parts of line taps

From pictures and actual samples provided by instructor

4.127 * Discuss stem type service valves

1. Integral part of compressor as access for service
2. Usually operated in one of three positions:
   A. Back-seated
   B. Front-seated
   C. Center-opened or cracked
3. Should never be in front-seated position on high side while system is operating
4. Should be in back-seated position before removing cap from gauge port
5. King valve
   A. On liquid line, usually after receiver
   B. Similar in construction to compressor service valve
   C. Can receive liquid charge when system is not operating

4.128 * List and identify parts of service valves

From pictures and actual valves provided by instructor

4.129 * Discuss charging of refrigerant into systems

1. Always charge vapor through low side if system is running.
2. It is possible to charge liquid through king or high side service valve when system is not operating.

4.130 * List steps for removing manifold gauge assembly from running system

1. Back-seat high side service valve, and close drum valve.
2. Leave low side service valve and low side manifold valve gauge open.
3. Leave compressor running--it will pull refrigerant into the low side.
4. Open high side manifold very slowly to allow refrigerant in high side hose to reenter system.
5. After short period, close low side manifold gauge valve and service valve.
6. Remove hoses, with minimum loss of refrigerant.

4.131 * Install line tap

1. On refrigerant line
2. Checking for leaks

4.132 * Install and remove refrigeration gauges

1. On service valves
2. With minimum of refrigerant loss
3. Wearing eye and hand protection

UNIT: Installing Oil Charge

4.133 * List the 7 essential qualities of refrigerant oil

1. Should:
   A. Maintain sufficient body to lubricate at high temperatures yet be fluid enough to lubricate at low temperatures
   B. Separate rapidly from refrigerants
   C. Be very dry
   D. Be stable
2. Should not:
   A. Carbonize
   B. Deposit wax
   C. React chemically

4.134 * List the 3 major classifications of mineral crude oil

1. Napthene base
2. Paraffin base
3. Mixed base

4.135 * List 3 reasons napthene base oils are better for refrigeration work

1. They flow better at low temperatures.
2. Their carbon deposits are of a soft nature.
3. They deposit less wax.

4.136 * Define terms

1. Viscosity
2. Pour point
3. Floc point
4. Neutralization number
5. Dielectric strength
6. Flash point
7. Oxidation stability
8. Phase separations
9. S.S.U. (Sabott Seconds Universal)

4.137 * Select proper oils

For systems described by instructor

EXAMPLE: Select oil for medium temperature walk-in R-12 system.

4.138 * Describe effect of temperature on oil viscosity

Increases as temperature decreases

4.139 * State what causes oil to turn to carbon

Coming into contact with hot surfaces causes oil to decompose and carbon to form.

4.140 * Describe way to determine floc point of oil

Cool mixture of 10% oil and 90% R-12 until oil forms little clusters noticeable to unaided eye.

4.141 * State what neutralization number indicates about an oil

Amount of mineral acid present

4.142 * Discuss importance of dielectric strength

1. Indicates impurities present in oil
2. Indicates presence of undesirable sulfur compounds

4.143 * State dielectric strength of good oils

25 KV

4.144 * Describe copper strip corrosion test

1. Measures corrosion tendency of refrigerant oil
2. Indicates presence of undesirable sulfur compounds
3. Negative score desirable

4.145 * Discuss color of refrigeration oil

1. Expressed numerically according to colorimeter
2. Should be light but not water-white

4.146 * State whether or not speed of release of refrigerant influences oil loss

Yes, so refrigerant should be released slowly.

4.147 * List 4 methods for measuring proper amount of oil in system

1. Weighing and installing oil with refrigerant in new system
2. Dip stick
3. Compressor sight glass
4. Paper method

4.148 * List 2 ways oil can be removed from system

1. Drain plugs
2. Loosened bottom plate
3. Hand pump
4. Suction pressure through tube in crankcase

4.149 * List 3 methods for charging oil into system

1. Pour
2. Suck into crankcase
3. Oil pump

4.150 * List 3 precautions to observe when charging or removing oil

1. Use clean, dry oil.
2. Control pressure when opening crankcase to atmosphere.
3. Avoid overcharging system.

4.151 * Remove and install oil in refrigeration unit

1. As assigned and evaluated by instructor
2. Using oil pump
3. Of equal amounts

UNIT: Charging with a Charging Cylinder

4.152 * List the 2 basic methods of replacing refrigerant charge

1. In liquid form
2. In vapor form

4.153 * State why system should be opened very slowly

To prevent oil loss

4.154 * List 2 methods for saving removed refrigerant

1. Use pump to transfer it to refrigerant drum used for this purpose only.
2. Transfer it through condenser coil to bottle stored in ice.

4.155 * State why torch should <u>not</u> be used to apply external heat to speed up evacuation

May cause decomposition of oil and/or refrigerant

4.156 * State what must be done before beginning charging

Leak test system

4.157 * State level to which to fill charging cylinder

With eight to ten ounces more than needed for job, but <u>never top calibration mark</u>

4.158 * State what liquid refrigerant does to skin and what you should do if it touches your skin

1. Causes severe burns
2. Get <u>immediate</u> medical attention.

4.159 * List 2 advantages of charging with charging cylinder

1. Can install almost precise amount of refrigerant resulting in predictable, normal system operation
2. Saves time

4.160 * List 8 precautions to take when charging with a cylinder

1. Handle the refrigerant cylinders carefully. Do not drop them.
2. Do not heat the cylinders with a torch.
3. Use a strap or chain to secure cylinders when transporting them, even on the cart.
4. Avoid refrigerant contact with the skin.
5. Do not inhale the refrigerant. Use only in a well ventilated area.
6. Secure large cylinders to a wall or bench.
7. Replace the cylinder cap when not using the cylinder to protect the valve.
8. Do not mix refrigerants.
9. Do not carry the refrigerant drum by the valve.
10. Remove the valve when discarding disposable cylinders.
11. Do not fill the charging cylinder above the highest calibration mark.
12. Open the service valve on line punctures very slowly to avoid oil loss.
13. Do not front-seat the high side service valve with the compressor operating.

4.161 * State side of system through which liquid charging is usually done

High side

4.162 * List metering device used in charging with a cylinder

1. Capillary tube(s)
2. TXV
3. AXV

4.163 * Describe way to drive liquid refrigerant from manifold hoses into system

1. Crack open low side manifold valve just enough to keep gauge at about 10 to 15 lbs. pressure.
2. Disconnect manifold center hose from base of charging cylinder, with cylinder valve closed, and connect to vapor valve on top of charging cylinder.

4.164 * Charge with charging cylinder

1. Evacuating cylinder to 1,000 microns, ±100 microns
2. Installing 48 oz. charge of refrigerant in charging cylinder
3. Evacuating refrigeration system
4. Installing 16 oz., ±1 oz. charge in system
5. With minimum refrigerant loss
6. Completing charge with refrigerant vapor

5. PIPEFITTING PROCEDURES

UNITS

Piping, Materials, and Fittings

Pipe Preparations

Tube Bending

Torches and Equipment

Soldering, Brazing, and Welding

Piping Practices and Pipe Sizing

Leak Detection and Repair

UNIT: Piping, Materials, and Fittings

5.01 * State type of pipe usually used in air conditioning and refrigeration

Type L copper tubing

5.02 * List 4 other types of pipe used in the industry

1. Plastic: For water piping or condensate drains
2. Galvanized: As above
3. Steel tubing: For condensers
4. Aluminum
5. Black pipe: For gas lines

5.03 * Describe fittings and their joining processes

1. Copper: Sweat fittings either soldered or silver brazed
2. Plastic: Slip fittings cemented together
3. Galvanized: Threaded fittings
4. Aluminum: Soldered or epoxied
5. Black pipe: Threaded fittings

5.04 * State what is placed in line of threaded piping that may be disassembled at later time

Union

5.05 * State type of tubing used where corrosion is a problem

Stainless steel

5.06 * Identify fittings from drawings

As assigned and evaluated by instructor

5.07 * Identify tubing by name, size, and application

1. From actual samples of L, M, and K copper, steel, and aluminum tubing
2. As provided and evaluated by instructor

5.08 * Identify fittings and pipes by name, size, and application

From actual samples provided by instructor

5.09 * Identify brass and copper pipe fittings by name, type, and size

From actual samples provided by instructor

UNIT: Pipe Preparations

5.10 * Describe what should be done to copper tubing before beginning cutting process

Clean area where cut is to be made with sandcloth.

5.11 * State correct turn ratio of lead screw to number of turns of tubing cutter

1/2 turn of lead screw to two to five turns of tubing cutter

5.12 * State precaution when using hacksaw to cut copper tubing

Make sure copper filings do not enter tubing.

5.13 * State type of hacksaw blade to use when cutting copper tubing

One with at least 24 teeth per inch

5.14 * State direction flare nut should be placed over tubing before flaring

With open end of nut towards open end of tubing

5.15 * Explain why handle of flaring tool should be backed off during flaring process

If it is not, tubing may become hardened and split the flare.

5.16 * State usual angle of flare

45°

5.17 * State what is needed for making good flares

Practice

5.18 * State purpose of swaging process

To allow two pieces of copper of same diameter to be joined without a fitting

5.19 * State whether copper tubing becomes shorter or longer during swaging process

Shorter

5.20 * Describe swaged socket depth

Should equal diameter of tubing being swaged

5.21 * Describe results of driving swaging tool all the way into holding block

May become lodged in tubing and break end of swaging tool

5.22 * Cut copper tubing

1. Using 1/4", 3/8", and 1/2" sizes in 6" lengths
2. ± 1/32"
3. Removing burrs

5.23 * Flare copper tubing

1. Using 1/4", 3/8", and 1/2" sizes in 4" lengths
2. With no splits or burrs

5.24 * Swage copper tubing

1. Using 1/4", 3/8", and 1/2" sizes in 6" lengths
2. With no damage to tubing or tools
3. With no splits or burrs

UNIT: Tube Bending

5.25 * Identify tube benders by function

1. To make long radius bends: Spring bender
2. To make short radius bend: Mechanical bender

5.26 * Solve problems involving minimum radius of bend

As assigned and evaluated by instructor

EXAMPLE: State minimum radius of bend when bending 3/8" copper tubing with spring bender.

5.27 * Solve problems involving bend allowance

As assigned and evaluated by instructor

EXAMPLE: State bend allowance for 1/2" copper tubing with 3" radius 90° bend.

5.28 * State formula for amount of straight line length of material needed for bend

$$\frac{\text{Angle of bend}}{360} \times \left(\text{Inside radius of bend} + \frac{\text{Diameter of pipe}}{2} \right) \times 2\pi$$

5.29 * Solve problems involving amount of straight line length of material needed for bend

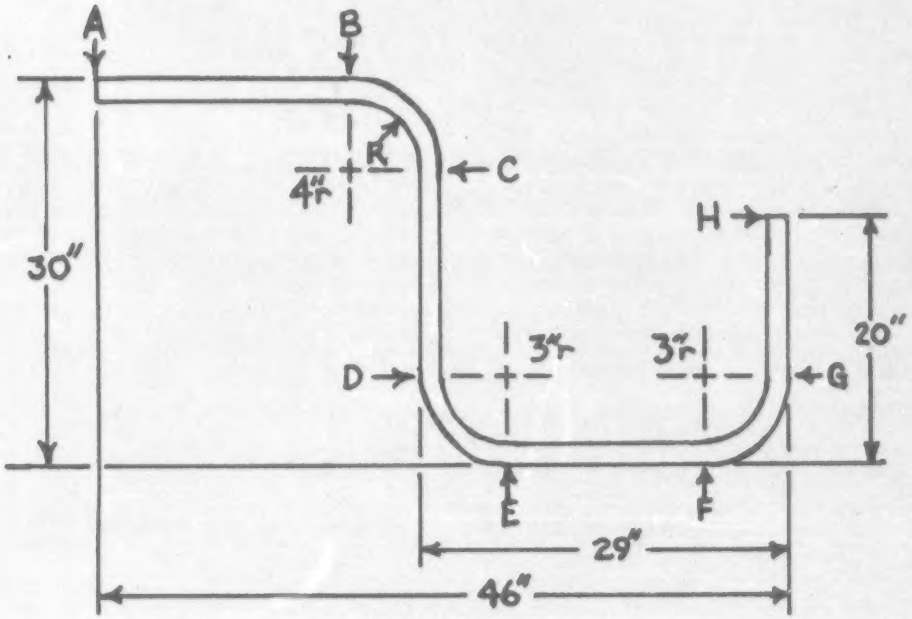
As assigned and evaluated by instructor

5.30 * State 2 dimensions to add together to find total length of copper tubing needed

Straight line length + Bend allowance

5.31 * Find straight line length and total length of copper tubing needed for specified project

1. As assigned and evaluated by instructor
2. As in sample below
3. Using 1/2" OD tubing
4. ±1/32"



5.32 * Make bends

1. As assigned and evaluated by instructor
2. Involving variety of bends
3. Using proper tools
4. ±1/16"

UNIT: Torches and Equipment

5.33 * List safety rules for working with welding equipment

1. Wear suitable, protective clothing and equipment.
2. Keep work area safe and clean.
3. Remove all flammable materials from area.
4. Never weld near explosives or carbon tetrachloride.
5. Always work in area with sufficient ventilation, and use cadmium free alloys whenever possible.
6. Handle all pressurized cylinders with care.
   NOTE: Acetylene can explode upon impact under pressure of 15 p.s.i. or more.
7. Never use oil or grease on oxygen or acetylene connections.
8. Never open tank valve until regulator valve is closed.
9. Never open tank valve with hammer.
10. Never hammer on oxygen or acetylene regulators.
11. Never light torch with match or open flame--use striker.
12. Be certain hose, tank, and any inflammable material are not exposed to heat, flame, or sparks before lighting torch.
13. Never use acetylene gas when pressure is above 15 p.s.i.
14. Never turn regulator screw in tight.
15. Do not hold welding tip too close to work at hand--flashback may result.
16. Repair cause(s) of hot tip/handle immediately.
17. Never use torch with leak, leave burning torch unattended, or leave torch valve open.
18. Never use torch or cylinders for any purposes other than those for which they are intended.
19. Never store torches in space where temperature exceeds 80°.
20. Never attempt to weld closed or jacketed tank, vessel, or container without vent hole for air.
21. Always use regulator on air acetylene torches.
22. Release pressure on regulator screw before opening cylinder valve.
23. Stand to one side of regulator, and open cylinder valve slowly.
24. Secure all cylinders so they cannot be knocked over.
25. Never use torch on closed pressurized container or refrigerant drum.
26. Never use oxygen as substitute for compressed air.

5.34 * Define terms

1. Inner cone
2. Outer cone
3. Presto-Lite
4. Flashback
5. Pressure regulator
6. MC tank
7. B tank

5.35 * Identify components of air-acetylene torch rig

1. Acetylene tank (MC and B)
2. Combination pressure-regulator-tank gauge
3. Hoses
4. Torch handle
5. Torch handle valve
6. Torch tip
7. Striker
8. Oxygen tank

5.36 * State whether turning regulator stem valve clockwise increases or decreases pressure on torch handle

Increases

5.37 * List types of threads on hose fittings

1. Acetylene hoses: Left-hand fittings
2. Oxygen hoses: Right-hand fittings

5.38 * State purpose of hole in base of torch tip

For air induction to support combustion of acetylene fuel

5.39 * State cause of flame with blowing, hissing sound and white inner cone

Excess fuel pressure on torch tip

5.40 * Select correct torch tips

1. For copper pipe diameters
   A. 1/8" C. 3/4" E. 2"
   B. 3/8" D. 1 1/2" F. 2 1/2"
2. For all class projects

5.41 * Assemble and light torch

1. Without leaks
2. Without pop-out or flashback

5.42 * Adjust torch flame

As explained and evaluated by instructor

UNIT: Soldering, Brazing, and Welding

5.43 * Discuss relative strength of soldering/brazing processes

1. Soft soldering: Least strong joint
2. Silver brazing: Stronger joint
3. Silver soldering: Strongest joint

5.44 * State purpose of flux when soft-soldering

1. Prevent oxidation of material
2. Flow out impurities present in joint

5.45 * Describe 95-5 solder

1. 95% tin and 5% antimony
2. Melting range: 452°-464°

5.46 * State amount of wire solder generally needed to soft-solder complete, well-tinned joint

1/4 to 1/2 of tubing diameter

5.47 * List steps in soldering

1. Thoroughly clean surfaces to be soldered.
2. Select proper flux.
3. Apply flux to make part of joint, to prevent flux from entering system.
4. Select proper tip.
5. Apply solder evenly to appropriately heated joint.
   NOTE: Always apply heat to joint, never to solder.
6. Clean excess flux from cooled joint.

5.48 * Describe a method of preventing solder from flowing into joint

Rub fingers lightly over last 1/8" of tubing to be joined.

5.49 * Solder joints

1. As assigned by instructor
2. With neat, solid joints and no leaks

5.50 * Describe Sil-fos

1. Rod
2. Melting point: 1140°-1150°F
3. Does not begin to flow until 1300°-1550°F, depending on silver content
4. Used for silver brazing
5. Does not require flux when joining copper to copper

5.51 * List 2 steps to avoid/prevent oxidation inside tubing when silver brazing

1. Blow nitrogen through tubing
2. Avoid overheating joint

5.52 * Describe way to know when correct silver brazing temperature is reached

When silver solder flows readily when in contact with joint

NOTE: Silver solder should be heated by the copper, not by the torch.

5.53 * Silver braze joints

1. As assigned by instructor
2. With neat, solid joints and no leaks

5.54 * Describe silver solder

1. Rod
2. Contains more silver (45%) than Sil-fos (5-15%)
3. Flow point very near that of Sil-fos
4. Requires flux
5. Requires nitrogen in tubing

5.55 * List steps in silver soldering

1. Thoroughly clean areas to be soldered.
2. Fit joints closely, and support all parts.
3. Apply appropriate flux.
4. Heat evenly to recommended temperature.
5. Apply silver brazing alloy to heated parts.
6. Clean cooled joints thoroughly.

5.56 * Describe motion of torch tip when preheating solder joint

Figure eight

5.57 * Silver solder joints

1. As assigned by instructor
2. With neat, solid joints and no leaks

5.58 * Describe aluminum solder

1. Roll or rod
2. Contains aluminum alloys
3. Flow temperature just below melting temperature of aluminum
4. Requires flux
5. Does not require nitrogen

UNIT: Piping Practices and Pipe Sizing

5.59 * State basic objective of good piping practices

To move refrigerant and oil properly and to return oil to compressor at same rate as it is being carried into the piping system

5.60 * Discuss tubing for refrigeration lines

1. Copper the usual choice
2. Welded steel pipe in fittings in sizes above 3" inches
3. Hard solder (silver, Sil-fos, or 95-5) normally used

5.61 * List 4 requirements of good refrigeration piping layout

1. Provide path for flow of refrigerant
2. Provide for smooth flow without excessive pressure drop
3. Return oil to compressor crankcase
4. Prevent liquid refrigerant or oil from entering compressor

5.62 * Identify lines by name, function, and considerations

1. Hot gas line
   A. Carry oil mixed with refrigerant from compressor to condenser
   B. Should be sized with velocity high enough to avoid problems with oil movement (usually for pressure drop equivalent to about 2°F change in saturated refrigerant temperature)
   C. Never insulated
   D. Pitched down from compressor to condenser
   E. May need riser or double riser, check valve, and/or muffler
   F. Considerations
      1) Pressure drop at full load must be within reasonable and practical limits.
      2) Oil return or circulation must be maintained under minimum load conditions.
      3) Refrigerant and oil must be prevented from draining back to head of compressor during off cycle.

2. Liquid line
   A. Returns oil
   B. Sized so it has very little pressure drop
   C. Flash gas a possible problem
   D. Not usually insulated
   E. Considerations
      1) Excessive pressure drop can result in loss of capacity at metering device.
      2) Pressure drops without sufficient subcooling will cause some of refrigerant to flash into gas.
      3) Pressure drops are caused by high friction and vertical rises in accessories.
3. Suction line
   A. Return dry refrigerant gas and intrained oil to compressor
   B. Sized so velocity is high enough to insure good oil return
   C. Most critical from layout standpoint
   D. May require risers or double risers
   E. Horizontal line pitched at 1/2"/10' of length
   F. Should not have traps close to compressor
   G. Should always be insulated
   H. Considerations same as those for hot gas lines
4. Condensate line
   A. Generously sized so gas formed in receiver flows back to condenser without restricting drainage of liquid refrigerant from condenser
   B. Requires separate gas equalizer when horizontal distance between condenser and receiver exceeds 6'

5.63 * List the 3 major considerations in refrigerant piping layout

1. Pressure drops
2. Oil return
3. Compressor protection

5.64 * List the 4 acceptable piping practices

1. Keep lines simple.
2. Pitch horizontal lines in direction of flow.
3. Avoid unnecessary pockets.
4. Allow for expansion and vibration absorption.

5.65 * Describe proper construction of oil trap

Either a preformed tube or constructed with a long radius ell and two street ells

5.66 * Describe method for insuring there will be no flash gas in liquid line

1. Determine pressure drop in liquid line.
2. Subtract pressure drop from condensing pressure.
3. Find temperature on saturated temperature-pressure chart corresponding to new pressure.
4. Subtract new temperature from condensing temperature.
5. Make sure condenser will provide at least this much subcooling.

5.67 * Solve problems involving refrigerant lines

As assigned and evaluated by instructor

EXAMPLE:

1. Given: A. Liquid R-22 leaving condenser at 240 PSIA
   B. Pressure drop total lift and friction equal to 17 PSIA
2. Determine amount of subcooling required to prevent flash gas in liquid line

5.68 * Draw operational piping layout

1. Given:
   A. System operating at constant load with constant capacity compressor
   B. With
      1) TEV
      2) Muffler
      3) Oil separator
      4) Sight glass
      5) Check valve
2. Identifying all components in line

5.69 * Identify unacceptable portions of piping layout

1. From system piping layout provided by instructor
2. Listing acceptable substitutions

5.70 * Find pressure drop in liquid, hot gas, and suction lines

1. Given:
   A. Systems load
   B. Evaporator temperature
   C. Condenser temperature
   D. Friction loss table
   E. Pipe size and length
2. Including fittings for each size pipe

5.71 * Find correct pipe size for suction lines, liquid lines, hot gas lines, condensate lines, and double risers

Given:
A. Systems load
B. Minimum unloaded condition
C. Evaporator temperature
D. Condenser temperature
E. Refrigerant
F. Subcooling

As assigned and evaluated by instructor

UNIT: Leak Detection and Repair

5.72 * List the 4 major steps in leak detection and repair

1. Locate leak.
2. Prepare leak area for repair.
3. Open closed system.
4. Repair with proper materials.

5.73 * List the 2 reasons refrigeration systems must be absolutely gas tight

1. To prevent loss of refrigerant charge
2. To prevent air and moisture from entering system

5.74 * List 2 possible sources of leaks

1. Joints and fittings improperly made during installation
2. Line breakage due to:
   A. Vibration
   B. Gasket failure
   C. Other operating malfunctions

5.75 * State indication of leak in new system

Air cannot be evacuated.

5.76 * Discuss basic steps in pressure testing system for leaks

1. If system is not already charged with refrigerant, partially charge with refrigerant to 35 to 70 PSIG; then add inert gas (dry nitrogen or carbon dioxide) to build pressure to 150 to 175 PSIG for testing purposes.

   NOTE: Never use oxygen for pressurizing system--explosion may occur if oil is present.
2. Check each joint and potential leak area thoroughly with correct leak detector for refrigerant used.

5.77 * List 3 items to observe when checking in-service system for leaks

1. Evaporator pressure
2. Condenser pressure
3. Spots of oil

5.78 * Identify 4 most commonly used methods of leak detection and advantages and disadvantages of each

1. Halide torch
   A. Advantages
      1) Can detect very small leaks
      2) Inexpensive
   B. Disadvantages
      1) Open flame
      2) Hard to see in bright light
      3) Requires full bottle needing frequent replacement
2. Electronic
   A. Advantages
      1) Most sensitive type available
      2) Available at reasonable cost
   B. Disadvantages
      1) Can be used only in clean, uncontaminated atmosphere
      2) Requires skill to operate correctly
      3) Requires batteries or electrical outlet
3. Soap bubbles
   A. Advantages
      1) Simple and safe
      2) Pinpoints leak when used in conjunction with halide torch or electronic detector
   B. Disadvantages
      1) Must paint entire system with soap solution unless used with another method
4. Trace dye
   A. Advantages
      1) Works in areas not accessible to other methods
      2) Most useful in commercial refrigeration
   B. Disadvantages
      1) May clog small openings in system
      2) Hard to remove from system
      3) Will stain surroundings anytime refrigerant is released

5.79 * List 3 possible safety hazards when leak testing

1. Toxic refrigerant may cause poisoning.
2. Large quantities of refrigerant can displace oxygen in the air.
3. Phosgene gas is formed when refrigerant such as R-12, R-22, R-500, and R-502 come in contact with flame in halide leak detector.

5.80 * List components of halide torch

1. Sniffer tube opening
2. Sniffer tube
3. Valve
4. Copper element
5. Opening to see flame color

5.81 * State type of refrigerants halide torch detects

Halogen

5.82 * Describe flame colors when halide torch finds leaks

1. Slight leak: Green
2. Large leak: Brilliant purple

5.83 * Locate leaks

1. Using at least the halide torch, electronic detector and soap bubbles methods
2. Locating and marking leak source(s)
3. Safely and without error

5.84 * Discuss materials used to repair leaks

1. Copper: Silver solder, Stay-Bright, Sil-fos
2. Aluminum: Epoxy materials

   NOTE: Aluminum soldering materials have been developed but require considerable knowledge to use.

3. Fittings: Replace
4. Leak in line, such as that caused by two lines rubbing together: Replace piece of line and join with soft solder, Sil-fos, silver solder
5. Steel: Silver solder

5.85 * State why system should be opened during repair process

So pressure from heat of torch flame can escape somewhere other than area of leak

5.86 * State which leaks are most difficult to repair

Those in condensers and evaporators

5.87 * State why leak repairs must be cleaned

If flux is left on the repair, it will cause the tubing to corrode.

5.88 * List where leaks are most often found

At:
1. Tubing connections
2. Flares
3. Fittings
4. Sweat joints

5.89 * State why 1" of aluminum fin must be removed from each side of leak area on tube and finned evaporators and condensers

The fins serve as heat-sink, transferring heat from torch away from line to be repaired.

5.90 * Repair leaks

1. Kinds
   A. Fitting
   B. Refrigerant line
   C. Condenser
   D. Evaporator
2. Selecting proper repair materials
3. Making solid, neat repair

DALLAS COUNTY COMMUNITY COLLEGE DISTRICT

AIR CONDITIONING AND REFRIGERATION

STUDENT PROFILE

School _____ School Stamp or Seal

Verification Signature _____
School Official

Date _____

Student's Name _____ Birthdate _____ SS# _____

Address _____ City _____ State _____ Zip _____

PLEASE TRANSMIT STUDENT PROFILE TO COLLEGE REGISTRAR AS SOON AS IT IS READY FOR EVALUATION.

I. FUNDAMENTALS OF ELECTRICITY		Mastered
Safety		
1.01	* List most common causes of laboratory accidents and ways to prevent them	
1.02	* List general precautions to prevent lab accidents	
1.03	* List steps to take if lab partner receives electrical shock	
1.04	Practice good safety habits and correct laboratory procedures	
1.05	* Read information sheet on safety	
1.06	* Pass Safety Test	
Introduction to Electricity		
1.07	* Define terms and indicate symbols as appropriate	
1.08	* Describe atoms	
1.09	* Distinguish between conductors and insulators	
1.10	* List 4 good conductors and 4 good insulators	
1.11	* List the 3 terms used to describe force that causes electrons to flow	
1.12	* List 3 common ways to produce voltage	
1.13	List 3 types of conductors used at your facility	
1.14	List 3 types of insulators used at your facility	
1.15	List 2 methods for producing voltage used at your facility	
Meters		
1.16	* State meter range switch setting of voltmeter when measuring voltage of unknown value	
1.17	* State range switch setting when voltmeter is not in use	
1.18	* Read AC and DC voltages	
1.19	* State jack in which test probes should be placed when using larger printed values on range switch	
1.20	* State why voltmeter should be placed on its back	
1.21	* Solve problems involving voltmeter at your work station	
1.22	* Select meter(s) capable of measuring resistance in ohms	
1.23	* State why power must be off when using ohmmeter	
1.24	* List 2 reasons ohmmeter should not be left on the ohms scale when not in use	
1.25	* State what should be checked whenever ohm scale is changed	
1.26	* State proper voltage of circuit when measuring its resistance	
1.27	* State position of function switch when measuring resistance with a multimeter	
1.28	* List 3 safety rules for working with ohmmeter	
1.29	* Solve problems involving ohmmeter	
1.30	* Select meter(s) capable of measuring current flow in amperes	
1.31	* State why in-line ammeter should never be placed across a voltage source	
1.32	* State scale setting of range switch when measuring current	
1.33	* State whether or not voltages used in connection with ammeter can cause electric shock	

CONTINUED

1.34	* State shunt switch placement in circuit that will protect in-line ammeter	
1.35	* State scale to start with when placing ammeter in a circuit	
1.36	* Identify needle position, range switch used, and test lead jack	
1.37	* Read current for range switches	
1.38	* Solve problems using ammeter	
Voltage, Current, and Resistance		
1.39	* List the 3 common measurements of properties of electricity, and give letter symbols for each	
1.40	* Discuss relationship of voltage, current, and resistance	
1.41	* Write Ohm's Law	
1.42	* State what Ohm's Law is used for	
Ohm's Law		
1.43	* Discuss rearrangement of Ohm's Law formula	
1.44	* Rearrange equation to solve for voltage	
1.45	* Rearrange equation to solve for resistance	
1.46	* Calculate voltage, current, and resistance	
Relationship of Work and Power		
1.47	* Discuss relationship of work and power	
1.48	* Discuss work and power as they apply to an electrical circuit	
1.49	* Describe power formula	
1.50	* Calculate instantaneous power in simple circuit	
Kilowatt Hours		
1.51	* State formula for watt hours	
1.52	* State number of watts in one kilowatt	
1.53	* State formula for kilowatt hours	
1.54	* Calculate total power consumed over period of time	
Introduction to Alternating Current and Direct Current		
1.55	* List characteristics of a circuit	
1.56	* Discuss polarity and current flow	
1.57	* List characteristics of direct current (DC)	
1.58	* List characteristics of alternating current (AC)	
1.59	* State why direction of current flow repeatedly reverses itself in an AC circuit	
1.60	* Draw and label complete circuit	
Series Circuits		
1.61	* Describe series circuit	
1.62	* Identify series circuits	
1.63	* Draw and label series circuit	
1.64	* Describe total resistance	
1.65	* State formula for total resistance in series circuit	
1.66	* State what happens to current when total resistance is increased and voltage stays the same	
1.67	* Describe current in series circuit	
1.68	* Describe voltage in series circuit	
1.69	* Discuss Kirchoff's Voltage Law	
1.70	* Calculate unknowns involving resistance in series circuit	
1.71	* Calculate unknowns involving current and voltage in series circuit	
1.72	* Calculate amounts of current, resistance, and voltage in series circuit constructed by student	
Parallel Circuits		
1.73	* Describe parallel circuit	
1.74	* Identify parallel circuits	
1.75	* Draw and label parallel circuit	
1.76	* Describe voltage in parallel circuit	
1.77	* Describe current in parallel circuit	
1.78	* List 2 methods for finding total resistance in parallel circuit	
1.79	* Calculate unknowns involving current and resistance in parallel circuit	
1.80	* Calculate amounts of current, resistance, and voltage in parallel circuit constructed by student	
Series-Parallel Circuits		
1.81	* Describe series-parallel circuit	
1.82	* Identify series-parallel circuits	
1.83	* Draw and label series-parallel circuit	
1.84	* Describe current flow through series-parallel circuits	
1.85	* Describe way to find total resistance in series-parallel circuit	
1.86	* Calculate total resistance in series-parallel circuit	
1.87	* Calculate total resistance using circuit constructed by student	

CONTINUED

FUNDAMENTALS OF ELECTRICITY (Continued)

Common Causes of Circuit Failure		
1.88	* Discuss interruption of current flow	
1.89	* List 3 common causes of short circuits	
Introduction to Magnetism		
1.90	* Discuss properties of magnetism	
1.91	* List 2 characteristics of magnets	
1.92	* Discuss types and properties of artificial magnets	
1.93	* Describe magnetic field or lines of flux	
1.94	* Describe flux density	
1.95	* Discuss permeability	
1.96	Make a permanent magnet	
Magnetism and Electricity		
1.97	* Discuss relationship of magnetism and electricity	
1.98	* Describe reactions of two magnetic fields	
1.99	* Discuss the electromagnet	
Induced Voltage		
1.100	* List the 3 elements needed to induce voltage	
1.101	* State what is needed for relative motion	
1.102	* Describe what happens when conductor passes through a magnetic field	
1.103	* State what determines amount of voltage induced	
1.104	* Discuss effects of conductor movement	
Sine Waves		
1.105	* Describe sine wave	
1.106	* Discuss cycle of sine wave	
1.107	* State way frequency is expressed	
1.108	* Discuss effective voltage	
1.109	* Draw sine wave	
1.110	* Calculate approximate effective value of AC	
Resistance and Inductance		
1.111	* List the 3 properties which oppose current flow	
1.112	* Describe purely resistant circuit	
1.113	* Describe purely inductive circuit	
1.114	* State whether current leads or lags voltage in an inductive circuit	
1.115	* List 2 practical applications of inductance to AC circuit	
Capacitance		
1.116	* State way capacitance is measured	
1.117	* Describe capacitor	
1.118	* List 2 factors affecting capacitance	
1.119	* Describe capacitance in AC circuit	
1.120	* State whether current leads or lags voltage	
1.121	* State common use for capacitors	
1.122	State Ohm's Law formulae involving reactance	
1.123	State formulae for total inductance and total capacitance of circuit	
1.124	Discuss combined resistance, inductance, and capacitance in an AC circuit	
1.125	* Discuss power factor	
1.126	* Describe determination of power in AC circuit	
1.127	* State type of electrical charges that create electrical field when built up	

CONTINUED

Transformers		
1.128	* State function of transformers and how they operate	
1.129	* List 3 principal parts of transformer and function of each	
1.130	* List the 2 elements influencing voltage output of transformer	
1.131	* Describe step-up and step-down transformers	
1.132	* State purpose of transformers with 1:1 winding ratios	
1.133	* State reason alternating current must be applied to primary winding to get voltage in secondary winding	
1.134	* Solve problems involving step-up and step-down transformers	
1.135	* Describe effect of voltage changes on current	
1.136	* List and describe the 2 kinds of heat losses in transformers	
1.137	* Define terms	
1.138	* State use of laminations	

The student must complete all the core (*) competencies.

Teacher's Signature _____ Date _____

2. ADVANCED ELECTRICAL CIRCUITS	Mastered
Safety and Basic Electricity Review	
2.01 * List most common causes of laboratory accidents and ways to prevent them	
2.02 * List general precautions to prevent lab accidents	
2.03 * List steps to take if lab partner receives electrical shock	
2.04 * Practice good safety habits and correct laboratory procedures	
2.05 Read information sheet on safety	
2.06 * Pass Safety Test	
2.07 * Read AC and DC voltages	
2.08 * Solve problems involving voltmeter at your work station	
2.09 * State what should be checked whenever ohm scale is changed	
2.10 * State proper voltage of circuit when measuring its resistance	
2.11 * Solve problems involving ohmmeter	
2.12 * Select meter(s) capable of measuring current flow in amperes	
2.13 * State scale to start with when placing ammeter in a circuit	
2.14 * Solve problems using ammeter	
2.15 * Write Ohm's Law	
2.16 * State what Ohm's Law is used for	
2.17 * Discuss rearrangement of Ohm's Law	
2.18 * Calculate voltage, current, and resistance	
2.19 * Discuss relationship of work and power	
2.20 * Discuss work and power as they apply to an electrical circuit	
2.21 * Describe power formula	
2.22 * Calculate instantaneous power in simple circuit	
2.23 * State formula for watt hours	
2.24 * Calculate unknowns involving resistance in series circuit	
2.25 * Calculate unknowns involving current and voltage in series circuit	
2.26 * Calculate unknowns involving current and resistance in parallel circuit	
2.27 * Calculate amounts of current, resistance, and voltage in parallel circuit constructed by student	
2.28 * Calculate total resistance in series-parallel circuit constructed by student	
2.29 * Discuss the electromagnet	
2.30 * List the 3 elements needed to induce voltage	
2.31 * State what is needed for relative motion	
2.32 * Describe what happens when conductor passes through a magnetic field	
2.33 * Discuss effects of conductor movement	
2.34 * Describe sine wave	
2.35 * Discuss cycle of sine wave	
2.36 * State way frequency is expressed	
2.37 * Discuss effective voltage	
2.38 * Draw sine wave	
2.39 * Calculate approximate effective value of AC	
2.40 * List the 3 properties which oppose current flow	
2.41 * State whether current leads or lags voltage in an inductive circuit and vice versa	
2.42 * State way capacitance is measured	
2.43 * Describe capacitor	
2.44 * Discuss combined resistance, inductance, and capacitance in an AC circuit	
2.45 * Discuss power factor	
2.46 * Describe determination of power in AC circuit	
2.47 * Describe step-up and step-down transformers	
2.48 * State reason alternating current must be applied to primary winding to get voltage in secondary winding	
2.49 * Describe effect of voltage changes on current	

CONTINUED

Components, Symbols, and Circuitry of Air Conditioning Wiring Diagrams		
2.50	* List the 3 types of electrical diagrams used in heating, cooling, and refrigeration industry and purpose of each	
2.51	* Define terms	
2.52	* State major load of air conditioning system	
2.53	* Identify and draw symbols for loads	
2.54	* State major difference between contactor and relay	
2.55	* State difference between magnetic starter and contactor	
2.56	* Identify and draw symbols for relays and contactors	
2.57	* Explain why heating and cooling thermostats differ	
2.58	* Identify and draw symbols for switches	
2.59	* State purpose of overload	
2.60	* Identify and draw symbols for safety devices	
2.61	* Draw symbol for transformer	
2.62	* State purpose of fuse in system, and draw symbols	
Alternating Current, Power Distribution, and Voltage Systems		
2.63	* Define terms	
2.64	* State most common frequency of alternating current used in U.S.	
2.65	* List advantages of alternating current over direct current	
2.66	* Describe transmission of alternating current from generating plant to consumer	
2.67	* State most common electrical service to a residence	
2.68	* State difference between single-phase and three-phase alternating current	
2.69	* State voltages of system with Y transformer hookup	
2.70	* State voltage of system with delta transformer hookup	
2.71	* List an advantage and a disadvantage of delta electric system	
2.72	* Describe detection of Y and delta systems	
2.73	* Identify power in your lab as being a Y or delta system	
2.74	* Sketch delta and Y transformer hookup arrangements	
2.75	* List advantages of 208V-3Ø-60 Hz system	
2.76	Describe type of structures where 208V-3Ø-60 Hz systems are used	
Installation of Heating, Cooling, and Refrigeration Systems		
2.77	* State who lists standard wire sizes used in U.S. today	
2.78	* List the 4 factors to consider in sizing circuit conductors	
2.79	* List major disadvantage of aluminum wiring	
2.80	* Name source service technician should consult for wire-sizing problems	
2.81	* Define terms	
2.82	* List the 3 basic types of disconnect switch enclosures	
2.83	* Describe detection of faulty circuit breaker	
2.84	* State most popular conductor in industry today	
2.85	* State purpose of disconnect switch	
2.86	* State purpose of main lug in breaker panel	
2.87	* Describe way to handle situation where no spare opening exists in breaker panel for installing equipment	
2.88	* List formulae for calculating voltage drop	
2.89	* Solve problems involving voltage drop	
2.90	* Solve problems involving supply voltage	
2.91	* Solve problems involving wire size	
2.92	* Identify different types of wire	
2.93	* Install solderless connectors on various sizes of wire	
Basic Electric Motors		
2.94	* Define terms	
2.95	* State what material conducts a magnetic field best	
2.96	* State whether or not unlike poles of a magnet repel each other and like poles attract	
2.97	* Describe part polarity plays in operation of electric motor	
2.98	* Discuss part frequency of alternating current plays in operation of electric motor	
2.99	* List and identify the 3 types of single-phase motors used in the industry	
2.100	* Describe operation of shaded-pole motor	
2.101	* Describe reversing of shaded-pole motor	

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2.102 * Describe why motor with only one winding will not start independently	
2.103 * Describe way split-phase motor produces phase displacement necessary to begin rotation	
2.104 * State when split-phase motors are used in relation to torque	
2.105 * State purpose of centrifugal switch in split-phase motor	
2.106 * State purpose of capacitor	
2.107 * List the 2 types of capacitors and the purpose of each	
2.108 * List the 5 capacitor replacement rules	
2.109 * Check capacitors	
2.110 * Replace capacitor	
2.111 * State reason for using capacitor in series with starting winding if winding is in parallel with running winding	
2.112 * State what creates phase displacement in PSC motor	
2.113 * List 4 advantages of using capacitor-start-capacitor-run motor	
2.114 * State major difference between split-phase and capacitor-start motors	
2.115 * State reason starting apparatus is unnecessary when using three-phase motor	
2.116 * List 4 advantages of three-phase motor over single-phase one	
2.117 * State reason all starting apparatus must be mounted externally to hermetic compressor	
2.118 * List steps in determining common, start, and run terminals of single-phase motor	
2.119 * Determine common, start, and run terminals of single-phase motor	
2.120 * Determine speed of motor, identify terminals, and check motors for opens, shorts, and shorts to ground	
2.121 * Draw wiring diagrams of motors	
Components for Electric Motors	
2.122 * State purpose of starting relays	
2.123 * Discuss the 3 types of starting relays used in the industry	
2.124 * List the 2 types of bearings most used and advantages and disadvantages of each	
2.125 * Define "direct drive," and state way(s) it is used in the industry	
2.126 * State why V-belts are popular in the industry	
2.127 * Describe correct tension on V-belt	
2.128 * Set correct tension on V-belt	
2.129 * Define terms	
2.130 * List the 3 types of magnetic starters used in the industry, and describe operation of each	
2.131 * State whether or not there will be ampere draw through starting circuit after motor reaches full speed with properly working starting relay	
2.132 * List lubrication methods for both ball and sleeve bearings	
2.133 * State whether or not overlubrication of motor and bearings is as damaging as underlubrication	
2.134 * State where ball bearings cannot be used	
2.135 * Lubricate and check bearings in variety of motors	
2.136 * Draw wiring diagrams of motors with different types of relays	
2.137 * Wire up motors and relays	
Contactors, Relays, and Overloads	
2.138 * State largest electric load in air conditioning or refrigeration system	
2.139 * Describe differences between contactors and relays and magnetic starters	
2.140 * List and describe operation of the 2 types of armatures used in contactors	
2.141 * List the 3 major sections of a contactor	
2.142 * State what contactors are made of	
2.143 * Describe procedure for checking contactor coil	
2.144 * Check contactors	
2.145 * List 2 major reasons for replacing contacts	
2.146 * State whether or not voltage reading taken across contacts of same pole will show voltage drop across contacts	
2.147 * State easiest faults to diagnose with contactors	
2.148 * List components of relay	
2.149 * State whether or not contacts in relays are easy to check by visual inspection	
2.150 * Define "normally open" and "normally closed" in reference to relays and contactors	

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ADVANCED ELECTRICAL CIRCUITS (Continued)

2.151 * State purpose of overload	
2.152 * Define "resistive overload" and "inductive overload"	
2.153 * List what fuses are most often used to protect	
2.154 * State what line break overload breaks	
2.155 * Describe operation of line break overload	
2.156 * State what pilot duty overload breaks	
2.157 * Describe operation of the 2 basic types of pilot duty overloads	
2.158 * State advantage of internal compressor overload	
2.159 * Describe procedure for checking internal compressor overload	
2.160 * Describe operation of fan relay	
2.161 * Check fan relay using ohmmeter	
Thermostats, Pressure Switches, and Other Electric Control Devices	
2.162 * State purpose of thermostat	
2.163 * List the 2 types of thermostats, and describe differences in their operation	
2.164 * Describe operation of remote bulb thermostat	
2.165 * State why contacts of thermostat should be snap-acting	
2.166 * List the 2 elements commonly used to provide snap-action	
2.167 * State where low-voltage thermostat is used	
2.168 * Describe difference between line voltage and low-voltage thermostats	
2.169 * State purpose of heating anticipator	
2.170 * Describe procedure for checking thermostat	
2.171 * State purpose of starting thermostat	
2.172 * State why two-stage heating thermostats are used on heat pumps	
2.173 * Define terms and letter designations	
2.174 * State purposes of low-pressure and high-pressure switches	
2.175 * Describe way low-pressure switch can be used as an operating control on refrigeration system	
2.176 * State purpose and describe operation of transformer	
2.177 * Describe procedures for checking transformer	
2.178 * State way capacity of transformer is rated	
2.179 * List precautions to take when replacing transformers	
2.180 * List the 2 pressures oil safety control operates on in refrigeration system	
2.181 * State purpose of time-delay relay	
2.182 * List 3 uses of time clock in heating and cooling system	
2.183 * Draw wiring diagram of low-voltage thermostat, and identify terminals	
2.184 * Wire low-voltage thermostat into air conditioning circuit	
2.185 * Wire pressure switches into AC circuit	
Troubleshooting Electric Control Devices	
2.186 * State first step in troubleshooting any system or component	
2.187 * Describe voltage check to diagnose condition of set of contacts in relay or contactor	
2.188 * State difference between resistance readings of open and shorted coils	
2.189 * Describe way to check fuse	
2.190 * Describe way to check circuit breaker	
2.191 * Describe way to proceed if line voltage overload is weak	
2.192 * State difference between line voltage overload and pilot duty overload	
2.193 * State what must be allowed to happen to hermetic compressor before condemnation	
2.194 * List steps in diagnosing bad pressure switch	
2.195 * Troubleshoot electric control devices, and make needed repairs/replacements	
Air Conditioning Control Systems	
2.196 * State purpose of air conditioning control system	
2.197 * State major difference between controls on small residential condensing unit and large commercial one	
2.198 * Define terms	
2.199 * State what internal pressure relief valve replaces in compressor	
2.200 * Draw diagram of wiring of simple residential air-cooled condensing unit	
2.201 * Describe connection of low and high-pressure switches in electrical system of residential system	

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Control Systems: Circuitry and Troubleshooting	
2.202 * List 3 components common to all control systems	
2.203 * State what controls condenser fan motor on residential systems	
2.204 * State whether or not safety controls in smaller systems are connected in parallel with contactor coil	
2.205 * State reason capacity control is used on larger systems	
2.206 * Describe function of part winding motor	
2.207 * State whether or not fan motors in larger systems are generally designed to operate at all times	
2.208 * Describe way constant head pressure is maintained	
2.209 * Describe function of low-voltage control system in larger systems	
2.210 * Define and describe operation of pump-down control system	
2.211 * Outline general procedure for troubleshooting a control system	
2.212 * Define "hopscotching"	
2.213 * Describe operation of and solve problems involving "packaged unit"	
2.214 * Describe operation of and solve problems involving heat pump	
2.215 * Troubleshoot electric control systems, and make needed adjustments/ repairs/replacements	

The student must complete all the core (*) competencies.

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Teacher's Signature Date

3. BASIC PRINCIPLES OF REFRIGERATION	Mastered
Heating and Cooling Safety	
3.01 Read information sheet on safety	
3.02 * Pass Safety Test	
Fundamentals	
3.03 * Define terms	
3.04 * List the 4 temperature scales used in refrigeration	
3.05 * List formulae for converting temperatures	
3.06 * Convert temperatures among scales	
3.07 * Describe difference between latent and sensible heat	
3.08 * State BTU needed to change ice to water and water to steam	
3.09 * State sensible heat of water	
3.10 * List formulae for heat	
3.11 * Solve problems involving heat	
3.12 * Calculate changes in heat of actual substances	
3.13 * State whether or not temperature of melting ice remains constant	
3.14 * List the 3 states of matter	
3.15 * List ways pressure is measured	
3.16 * State what determines conditions at which substance may boil, vaporize, or condense	
3.17 * List 6 rules governing pressure and temperature	
3.18 * Solve problems involving pressure and temperature	
3.19 * State condition where liquid and vapor coexist simultaneously within certain space	
3.20 * Describe subcooled matter	
3.21 * List steps in determining number of degrees liquid refrigerant has been subcooled	
3.22 * State what determines saturated temperature of refrigerant	
3.23 * Describe way to determine vapor pressure exerted at specific saturated temperature of refrigerant	
3.24 * Discuss superheat	
3.25 * Solve problems involving saturation, superheat, and subcooling	
3.26 * Determine conditions of refrigerant	
3.27 * List pressure formulae	
3.28 * Convert pressures	
3.29 * State lb./sq. in absolute in 1 in. of mercury vacuum	
3.30 * Read pressures in gauge absolute and inches of mercury, and observe effects of pressure	
3.31 * State type of gauge most used in refrigeration industry	
3.32 * List instruments used for more accurate measurement of negative pressures	
3.33 * Describe expression of pressures related to atmospheric pressures	
3.34 * List the 4 refrigerant conditions pressure affects	
3.35 * Solve problems involving effects of pressure	
3.36 * State whether or not condensing pressure and temperature must be above ambient conditions to remove heat from condenser absorbed in evaporator	
3.37 * List laws involving gases	
3.38 * List 3 rules involving gases	
3.39 * Solve problems involving gas laws and the perfect equation	
3.40 * Solve problems dealing with gas laws	
Compression System of Refrigeration	
3.41 * State factor determining whether to charge with vapor or with liquid	
3.42 * State what determines point in system where refrigerant will actually enter	
3.43 * List the 4 basic methods of determining whether proper amount of refrigerant is being introduced	
3.44 * Discuss charging by superheat	
3.45 * Solve problems involving charging without a charging cylinder	
3.46 * Explain why service drum should never be turned upside down when charging through low side	
3.47 * State cause of frost on service drum and way to speed up charging process	
3.48 * List 4 precautions to take when charging without a cylinder	
3.49 * Install liquid charge	
3.50 * Install vapor charge	

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BASIC PRINCIPLES OF REFRIGERATION (Continued)

Refrigerants	
3.51 * Define terms as they relate to refrigerants	
3.52 * Identify refrigerants by color code	
3.53 * List 4 toxic refrigerants	
3.54 * List 5 flammable refrigerants	
3.55 * List 4 nonflammable refrigerants	
3.56 * List 10 safety precautions when working with refrigerants	
3.57 * List 4 characteristics/properties of a good refrigerant	
3.58 * State what occurs when a halogen refrigerant comes in contact with an open flame	
3.59 * List 5 secondary refrigerants	
3.60 * State boiling points of R-22 and R-12	
3.61 * State formula for cu. ft. per minute per ton	
3.62 * List 6 characteristics of refrigerants	
3.63 * Solve simple refrigerant problems	
3.64 * Find points in system where refrigerant is saturated and superheated	
3.65 * Select proper refrigerant for system	
Dehydration	
3.66 * List the 2 ways moisture may exist in a refrigeration system	
3.67 * Describe way to avoid freeze-ups	
3.68 * Solve problems involving solubility of water in liquid refrigerants	
3.69 * Describe best place to install moisture indicators	
3.70 * List 2 reasons dryers should be located close to expansion valve or capillary tube	
3.71 * List 8 sources of contamination	
3.72 * List 5 harmful effects of contaminants	
3.73 * List 4 major causes of corrosion	
3.74 * Describe way to remove contaminants	
3.75 * List 4 factors determining time required to remove water and air	
3.76 * State gauge recommended for following course of evacuation	
3.77 * Explain need for vacuum pump with deep vacuum capabilities when evacuating refrigeration system	
3.78 * State preferred evacuation method considering time and efficiency	
3.79 * Solve problems involving Vacuum Steam Table	
3.80 * Select correct drying methods	
3.81 * Evacuate system using mercury manometer	
3.82 * Evacuate system using thermocouple vacuum meter	
3.83 * Install purge charge	
3.84 * Describe the 2 types of hermetic motor burn-outs	
3.85 * Describe way to determine extent of burn-out in welded hermetic motor	
3.86 * Discuss causes of burn-outs	
3.87 * List 5 products of decomposition	
3.88 * List the 2 most difficult contaminants to remove and the best way to do so	
3.89 * Discuss use of suction line filter-dryer in cleaning system	
3.90 * Discuss the 2 basic methods of cleaning a system after a burn-out	
3.91 * State most important thing to do before replacing compressor motor after burn-out	
3.92 * List probable cause(s) of burn-out in actual unit	
3.93 * Describe required clean-up action	
3.94 * Determine if refrigerant and/or oil can be salvaged	
Heat Calculations	
3.95 * Describe heat	
3.96 * List the 3 ways heat moves, and give example of each	
3.97 * State exactly what radiation heats	
3.98 * Determine direction of heat flow	
3.99 * Identify methods of heat transfer	
3.100 * List 3 environmental factors affecting human comfort	
3.101 * Define terms	
3.102 * List 2 examples of internal heat gains	
3.103 * List 2 examples of external heat gains	
3.104 * State whether or not activity of human body affects its temperature	
3.105 * List the design conditions for Dallas, Texas	
3.106 * State whether or not color of building surface affects heat gain	
3.107 * State formula for BTU/hr.	
3.108 * State number of BTU/hr./watt incandescent light adds	
3.109 * Calculate heat gains	
3.110 * Calculate co-efficient of heat transfer (U factor)	
3.111 * Find BTU/hr.	

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BASIC PRINCIPLES OF REFRIGERATION (Continued)

Properties of Air	
3.112 * Define terms	
3.113 * State number of grains of moisture in one lb. of water	
3.114 * State instrument used to measure wet bulb and dry bulb temperatures	
3.115 * State which thermometer has cotton wick over one end	
3.116 * List the 3 temperatures that will be the same if there is 100% humidity	
3.117 * State at what rate and for how long sling psychrometer should be slung	
3.118 * State minimum number of readings necessary for accuracy	
3.119 * Explain why wet bulb temperature is lower than dry bulb when relative humidity is less than 100%	
3.120 * List steps in use of sling psychrometer	
3.121 * List steps in finding relative humidity of air with sling psychometer	
3.122 * Find unknowns	
3.123 * List basic parts of psychrometric chart	
3.124 * State what process line indicates	
3.125 * List steps in drawing process line on psychrometric chart	
3.126 * Discuss changes in process line	
3.127 * Measure and record wet and dry bulb temperatures	
3.128 * Determine relative humidity of entering and leaving air	
3.129 * Draw process lines on psychrometric chart	
3.130 * Describe where on psychrometric chart A.D.P. is read	
3.131 * State what enthalpy scale on chart is used to determine	
3.132 * State formula for amount of sensible heat removed at standard air conditions BTU/hr.	
3.133 * State formula for amount of latent heat removed at standard air conditions BTU/hr.	
3.134 * State formula for amount of heat removed at other than standard conditions BTU/hr.	
3.135 * State formula for total heat removed from volume of air	
3.136 * Draw sensible heat ratio line of .70 for Dallas design conditions	
3.137 * Find A.D.P.	
3.138 * Plot psychrometric chart of entering and leaving air	
3.139 * Calculate total heat removed from given space in given amount of time	
3.140 * Describe effect on space if too much latent but not enough sensible heat is removed and vice versa	
Pressure-Enthalpy (Ph) Diagram	
3.141 * Define "enthalpy"	
3.142 * List 10 refrigerant conditions/properties possible to determine with Ph diagram	
3.143 * State major advantage of Ph diagram over saturation, refrigerant properties, and superheated vapor tables	
3.144 * Label major lines and areas of Ph diagram	
3.145 * State pressures used on Ph diagram	
3.146 * Describe how Ph diagram is useful in determining effects of changing refrigerant conditions	
3.147 * Draw skeleton Ph diagram, and identify the 4 processes	
3.148 * Solve problems involving Ph diagrams	
3.149 * Interpret Ph diagrams	

The student must complete all the core (*) competencies.

Teacher's Signature _____ Date _____

4. VAPOR COMPRESSION SYSTEMS	Mastered
Refrigeration System Processes and Components	
4.01 * Define terms	
4.02 * Identify 4 major components of refrigeration system by name and function	
4.03 * State formula for calculating compression ratio for compressor	
4.04 * List the 2 main types of condensers used in the industry today	
4.05 * List 6 types of metering devices	
4.06 * List the 2 places in the system where refrigerant changes states	
4.07 * Identify compressor, and calculate compression ratio	
4.08 * Identify condenser, and observe change in liquid level	
4.09 * Identify evaporator, and observe temperature changes	
Pressure-Enthalpy (Ph) Diagram	
4.10 * Define "enthalpy"	
4.11 * List 10 refrigerant conditions and properties possible to determine with Ph diagram	
4.12 * State major advantage Ph diagram has over saturation, refrigerant properties, and superheated vapor tables	
4.13 * Label major lines and areas of Ph diagram	
4.14 * State pressures used on Ph diagram	
4.15 * Explain how Ph diagram is useful in determining effects of changing refrigerant conditions	
4.16 * Draw skeleton Ph diagram, and identify the 4 processes	
4.17 * Solve problems involving Ph diagrams	
4.18 * Interpret Ph diagrams	
4.19 * Construct Ph diagram	
4.20 * Construct and interpret Ph diagram	
4.21 * Choose better set of conditions	
Thermostatic Expansion Valve (TEV)	
4.22 * Describe TEV	
4.23 * Identify parts of TEV	
4.24 * State name of pressure to adjust to change super heat on TEV	
4.25 * State what L on top of sporlan-type expansion valve signifies	
4.26 * Describe result of excessive flash gas in TEV	
4.27 * Describe where external equalizer should be attached to evaporator	
4.28 * State whether or not external equalizer should be capped	
4.29 * List 3 types of bulb charges	
4.30 * Select bulb charges	
4.31 * List advantages and disadvantages of the 3 bulb charges	
4.32 * List 3 advantages of C, G, or X valve	
4.33 * List 2 advantages of sporlan flowmaster type G	
4.34 * List steps to take when problems with TEV are suspected	
4.35 * Describe the 3 conditions an analysis will probably show	
4.36 * List 3 possible causes of low suction pressure and high super heat	
4.37 * List 3 possible causes of low suciton pressure and low super heat	
4.38 * List 3 possible causes of high suction pressure and low super heat	
4.39 * List 3 possible causes of floodback in evaporator during start up	
4.40 * State first correction to try when system is hunting or cycling and flooding back to compressor at same time	
4.41 * Define terms	
4.42 * State what discolored parts of TEV indicate	
4.43 * List steps in determining super heat	
4.44 * Solve problems involving super heat	
4.45 * Describe results of conditions affecting TEV's	
4.46 * State amount of super heat usually allowed on air conditioning system without affecting evaporator	
4.47 * Describe size of turn of adjustment stem when adjusting for correct super heat	
4.48 * State suggested time intervals between TEV adjustments for super heat	
4.49 * Disassemble and reassemble TEV	
4.50 * Install TEV	
4.51 * Adjust super heat	

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	Capillary Tubes	
4.52	* Describe capillary tube	
4.53	* Explain why capillary tube is known as "critical charged system"	
4.54	* Describe results of bonding capillary tube to suction line	
4.55	* List steps in cleaning restricted capillary tube	
4.56	* Clean capillary tube	
	Other Metering Devices	
4.57	* State purpose of metering device	
4.58	* Identify metering devices by name and special features	
4.59	* List metering devices in which flash gas might occur	
4.60	* Disassemble and reassemble automatic expansion valve	
4.61	* Observe operating automatic expansion valve	
	Evaporators	
4.62	* List the 2 basic types of evaporators	
4.63	* List 3 advantages of dry or direct expansion evaporators	
4.64	* List the 3 classifications of evaporator surfaces	
4.65	* List an advantage of dry expansion chillers	
4.66	* Solve problems involving evaporators	
4.67	* State which fluid flows through tubes of direct expansion chiller	
4.68	* List the 2 most often used secondary refrigerants	
4.69	* Identify evaporators	
4.70	* Measure and record ΔT of air over evaporators and liquid chillers	
4.71	* Adjust liquid flow rate	
	Defrost Methods and Devices	
4.72	* State cause and result of ice forming on evaporator	
4.73	* List the 5 most common methods of defrosting	
4.74	* Identify and list advantages and disadvantages of defrost methods of 3 different units	
4.75	* Describe electric defrost systems	
4.76	* List functions of bimetal switch	
4.77	* Describe hot-gas defrost system	
4.78	* Describe Vapot	
4.79	* Adjust hot-gas defrost system	
	Compressor Types	
4.80	* Identify compressors	
4.81	* Describe difference between serviceable and welded hermetic compressors	
4.82	* Identify compressors according to features	
4.83	* State only wearing parts of centrifugal compressor	
4.84	* List basic components of reciprocating compressor	
4.85	* Describe way hermetically sealed compressor is driven	
4.86	* List the 2 components totally enclosed in fully hermetic system	
4.87	* State where lubrication is needed in centrifugal compressor	
	Reciprocating Compressors	
4.88	* List the 4 types of seals most used in the industry today	
4.89	* List the 2 general types of lubrication systems used on reciprocating compressors	
4.90	* Identify components of reciprocating compressor	
4.91	* Identify parts of reciprocating compressor	
4.92	* State type of reciprocating compressor requiring mechanical shaft seal	
4.93	* Describe way all refrigeration compressor valves are opened and closed	
4.94	* State locations of the 2 types of piston rings	
4.95	* State what compressor valves are usually made of	
4.96	* List 3 guidelines for disassembling and assembling compressors	
4.97	* Disassemble compressor	
4.98	* Inspect component parts	
4.99	* Assemble compressor	

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VAPOR COMPRESSION SYSTEMS (Continued)

Compressor Capacity	
4.100 * State general reason for compressor control	
4.101 * List the 4 most common methods of controlling compressor capacity	
4.102 * State formula for calculating piston displacement of a compressor	
4.103 * Solve problems involving piston displacement of a compressor	
4.104 * Define terms	
4.105 * List 4 application factors that vary compressor capacity	
4.106 * State formula for calculating CFM compressor must have for certain load	
4.107 * Solve problems involving CFM	
4.108 * Identify types of compressor capacity control	
4.109 * List factors affecting capacity control for 2 compressors	
4.110 * Describe effect of clearance volume on compressor capacity	
Control and Service of Condensers	
4.111 * List the 2 basic media to which condensers reject their heat	
4.112 * List the 3 types of condensers	
4.113 * List the 4 basic types of water-cooled condensers	
4.114 * List the 2 major temperature guidelines for condensers	
4.115 * Describe disadvantage of double pipe condenser	
4.116 * State where natural draft air-cooled condenser is most likely found	
4.117 * State type of system on which vertical shell and coil condenser might be found	
4.118 * State types of fans used with forced air condensers	
4.119 * Solve problems involving condensers	
4.120 * State factor determining capacity of evaporative condenser	
4.121 * State variety of most heat removed from refrigerant in condenser	
4.122 * Service malfunctioning forced draft condenser	
4.123 * Determine BTU/hr. being rejected by water-cooled condenser	
4.124 * Set control device	
Service Valves	
4.125 * Discuss line taps	
4.126 * List and identify parts of line taps	
4.127 * Discuss stem type service valves	
4.128 * List and identify parts of service valves	
4.129 * Discuss charging of refrigerant into systems	
4.130 * List steps for removing manifold gauge assembly from running system	
4.131 * Install line tap	
4.132 * Install and remove refrigeration gauges	
Installing Oil Charge	
4.133 * List the 7 essential qualities of refrigerant oil	
4.134 * List the 3 major classifications of mineral crude oil	
4.135 * List 3 reasons napthene base oils are better for refrigeration work	
4.136 * Define terms	
4.137 * Select proper oils	
4.138 * Describe effect of temperature on oil viscosity	
4.139 * State what causes oil to turn to carbon	
4.140 * Describe way to determine floc point of oil	
4.141 * State what neutralization number indicates about an oil	
4.142 * Discuss importance of dielectric strength	
4.143 * State dielectric strength of good oils	
4.144 * Describe copper strip corrosion test	
4.145 * Discuss color of refrigeration oil	
4.146 * State whether or not speed of release of refrigerant influences oil loss	
4.147 * List 4 methods for measuring proper amount of oil in system	
4.148 * List 2 ways oil can be removed from system	
4.149 * List 3 methods for charging oil into system	
4.150 * List 3 precautions to observe when charging or removing oil	
4.151 * Remove and install oil in refrigeration unit	

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Charging with a Charging Cylinder

4.152 * List the 2 basic methods of replacing refrigerant charge	
4.153 * State why system should be opened very slowly	
4.154 * List 2 methods for saving removed refrigerant	
4.155 * State why torch should not be used to apply external heat to speed up evacuation	
4.156 * State what must be done before beginning charging	
4.157 * State level to which to fill charging cylinder	
4.158 * State what liquid refrigerant does to skin and what you should do if it touches your skin	
4.159 * List 2 advantages of charging with charging cylinder	
4.160 * List 8 precautions to take when charging with a cylinder	
4.161 * State side of system through which liquid charging is usually done	
4.162 * List metering devices used in charging with a cylinder	
4.163 * Describe way to drive liquid refrigerant from manifold hoses into system	
4.164 * Charge with charging cylinder	

The student must complete all the competencies.

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Teacher's Signature Date

5. PIPEFITTING PROCEDURES	Mastered
Piping, Materials, and Fittings	
5.01 * State type of pipe usually used in air conditioning and refrigeration	
5.02 * List 4 other types of pipe used in the industry	
5.03 * Describe fittings and their joining processes	
5.04 * State what is placed in line of threaded piping that may be disassembled at later time	
5.05 * State type of tubing used where corrosion is a problem	
5.06 * Identify fittings from drawings	
5.07 * Identify tubing by name, size, and application	
5.08 * Identify fittings and pipes by name, size, and application	
5.09 * Identify brass and copper pipe fittings by name, type, and size	
Pipe Preparations	
5.10 * Describe what should be done to copper tubing before beginning cutting process	
5.11 * State correct turn ratio of lead screw to number of turns of tubing cutter	
5.12 * State precaution when using hacksaw to cut copper tubing	
5.13 * State type of hacksaw blade to use when cutting copper tubing	
5.14 * State direction flare nut should be placed over tubing before flaring	
5.15 * Explain why handle of flaring tool should be backed off during flaring process	
5.16 * State usual angle of flare	
5.17 * State what is needed for making good flares	
5.18 * State purpose of swaging process	
5.19 * State whether copper tubing becomes shorter or longer during swaging process	
5.20 * Describe swaged socket depth	
5.21 * Describe results of driving swaging tool all the way into holding block	
5.22 * Cut copper tubing	
5.23 * Flare copper tubing	
5.24 * Swage copper tubing	
Tube Bending	
5.25 * Identify tube benders by function	
5.26 * Solve problems involving minimum radius of bend	
5.27 * Solve problems involving bend allowance	
5.28 * State formula for amount of straight line length of material needed for bend	
5.29 * Solve problems involving amount of straight line length of material needed for bend	
5.30 * State 2 dimensions to add together to find total length of copper tubing needed	
5.31 * Find straight line length and total length of copper tubing needed for specified project	
5.32 * Make bends	
Torches and Equipment	
5.33 * List safety rules for working with welding equipment	
5.34 * Define terms	
5.35 * Identify components of air-acetylene torch rig	
5.36 * State whether turning regulator stem valve clockwise increases or decreases pressure on torch handle	
5.37 * List types of threads on hose fittings	
5.38 * State purpose of hole in base of torch tip	
5.39 * State cause of flame with blowing, hissing sound and white inner cone	
5.40 * Select correct torch tips	
5.41 * Assemble and light torch	
5.42 * Adjust torch flame	

CONTINUED

PIPEFITTING PROCEDURES (Continued)

Soldering, Brazing, and Welding		
5.43	* Discuss relative strength of soldering/brazing processes	
5.44	* State purpose of flux when soft-soldering	
5.45	* Describe 95-5 solder	
5.46	* State amount of wire solder generally needed to soft-solder complete, well-tinned joint	
5.47	* List steps in soldering	
5.48	* Describe a method of preventing solder from flowing into joint	
5.49	* Solder joints	
5.50	* Describe Sil-fos	
5.51	* List 2 steps to avoid/prevent oxidation inside tubing when silver brazing	
5.52	* Describe way to know when correct silver brazing temperature is reached	
5.53	* Silver braze joints	
5.54	* Describe silver solder	
5.55	* List steps in silver soldering	
5.56	* Describe motion of torch tip when preheating solder joint	
5.57	* Silver solder joints	
5.58	* Describe aluminum solder	
Piping Practices and Pipe Sizing		
5.59	* State basic objective of good piping practices	
5.60	* Discuss tubing for refrigeration lines	
5.61	* List 4 requirements of good refrigeration piping layout	
5.62	* Identify lines by name, function, and considerations	
5.63	* List the 3 major considerations in refrigerant piping layout	
5.64	* List the 4 acceptable piping practices	
5.65	* Describe proper construction of oil trap	
5.66	* Describe method for insuring there will be no flash gas in liquid line	
5.67	* Solve problems involving refrigerant lines	
5.68	* Draw operational piping layout	
5.69	* Identify unacceptable portions of piping layout	
5.70	* Find pressure drop in liquid, hot gas, and suction lines	
5.71	* Find correct pipe size for suction lines, liquid lines, hot gas lines, condensate lines, and double risers	
Leak Detection and Repair		
5.72	* List the 4 major steps in leak detection and repair	
5.73	* List the 2 reasons refrigeration systems must be absolutely gas tight	
5.74	* List 2 possible sources of leaks	
5.75	* State indication of leak in new system	
5.76	* Discuss basic steps in pressure testing system for leaks	
5.77	* List 3 items to observe when checking in-service system for leaks	
5.78	* Identify 4 most commonly used methods of leak detection and advantages and disadvantages of each	
5.79	* List 3 possible safety hazards when leak testing	
5.80	* List components of halide torch	
5.81	* State type of refrigerants halide torch detects	
5.82	* Describe flame colors when halide torch finds leaks	
5.83	Locate leaks	
5.84	* Discuss materials used to repair leaks	
5.85	* State why system should be opened during repair process	
5.86	* State which leaks are most difficult to repair	
5.87	* State why leak repairs must be cleaned	
5.88	* List where leaks are most often found	
5.89	* State why 1" of aluminum fin must be removed from each side of leak area on tube and finned evaporators and condensers	
5.90	* Repair leaks	

The student must complete all the competencies.

Teacher's Signature _____ Date _____

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